EXAMINATION OF WATER

CHEMICAL AND BACTERIOLOGICAL

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PREFACE

KNOWLEDGE of quantitative analysis is here necessarily assumed; therefore the merest suggestions are given for determination of the mineral matters present in a water, while the items properly lying within the scope of a sanitary examination are dealt with more at length.

Upon the bacteriological side, only so much is touched upon as has been demonstrated to be of real service to the water-examiner; leaving the great field of ultimate differentiation to be further explored, and rendered still more practically useful, by the professed bacteriologist.

Sundry tests contained in former editions have been omitted and others, more suited to modern practice, have been added in their place.

Effort has been made to place the analytical methods in harmony with the recommendations of the 1917 Report of the " Standard Methods " Committee of the American Public Health Association, but it has been considered best not to quote directly

upon too extensive a scale from that standard work, for the reason that its excellence as a book of reference interferes somewhat with its value as a working text for students' use.

RENSSELAER POLYTECHNIC INSTITUTE, TROY, N. Y.
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EXAMINATION OF WATER

CHAPTER I

INTRODUCTORY

A GREAT deal of popular misconception exists upon the subject of the analysis of potable water, and it is commonly supposed that such an examination may be looked upon from practically the same point of view as the analysis of an iron ore. That this belief is founded on fallacy may, however, be readily shown. When an iron ore is submitted for analysis the chemist determines and reports upon the percentages of iron, phosphorus, sulphur, etc., found therein; and at that point his duties usually cease, inasmuch as the ironmaster is ordinarily capable of interpreting the analysis for himself. Even should the analyst be called upon for an opinion as to the quality of the ore, the well-known properties of the several constituents make such a task an easy one, and, assuming the sample to have been fairly selected, the opinion may be written without any inquiry as to the nature of

the local surroundings of the spot whence the ore was taken.

A water-analysis, on the other hand, is really not an analysis at all, properly so called, but is a series of experiments undertaken with a view to assist the judgment in determining the potability of the supply. Although "Standard Methods" have been published, the manner of conducting these experiments is still largely influenced by the individual preferences of the analyst, and are far from being uniform or always capable of comparison, thus often introducing elements of confusion where two or more chemists are employed to analyze the same water. Some of the substances reported—"albuminoid ammonia," for instance—do not exist ready formed in the water at all, and are but the imperfect experimental measures of the objectionable organic constituents, which our present lack of knowledge prevents our estimating directly.

Thus the numerical results of a water-analysis are not only unintelligible to the general public, but are not always capable of interpretation by a chemist unless he be acquainted with the surroundings of the spot whence the sample was drawn, and be posted as to the analytical methods employed.

It was formerly very common for water to be sent for analysis, with the request that an opinion be

returned as to its suitability for potable uses, while at the same time all information as to its source was not only unfurnished, but was intentionally withheld, with a view of rendering the desired report unprejudiced in character.

Such action was not only a reflection upon the moral quality of the chemist, but it seriously hampered him in his efforts to formulate an opinion from the analytical results.

For instance, a large quantity of common salt is a cause for suspicion when found in drinking-water, not because of any poisonous property attaching to the salt itself, but because it is usually difficult to explain its presence in quantity except upon the supposition of the infiltration of sewage. Thus an amount of salt sufficient to condemn the water from a shallow well in the Hudson valley could be passed as unobjectionable if found in a deep-well water from near Syracuse, N. Y.

The writer once saw the contents of an ice-cream freezer dumped within a few feet of the mouth of a domestic well. So large an amount of salt thrown upon the ground naturally increased the quantity of chlorine in the water, and might have led to the condemnation of the well had not the source of the chlorine been known.

Hence we see how important it is for the chemist

to be fully acquainted with the history of the water
he is to examine in order that he may compare his
results in " chlorine " with the " normal chlorine "
of the section whence the sample is taken.

A knowledge of the history of the water is no less
important in order to interpret the remaining items
of a water-analysis. Some time since, a water was
sent from Florida to the author for examination, and
was found to contain 1.18 parts " free ammonia "
per million. Much " free ammonia " commonly
points to contamination from animal sources, and
had it not been known that the water in question
was derived from the melting of artificial ice made
by the ammonia process, the enormous quantity of
ammonia found would have condemned it beyond a
peradventure. As it was, the water was pronounced
pure, the other items of the analysis having been
found unobjectionable.

Analytical results which would condemn a surface-
water may be unobjectionable for water from an
artesian well, for the reason that in the latter case
high figures in " free ammonia," " chlorine," or
" nitrates " are often capable of an explanation other
than that of sewage-infiltration. Even though such
a water should, at a previous period, have come in
contact with objectionable organic waste material,
yet the intervening length of time and great distance

of underground flow would probably have furnished abundant opportunity for thorough purification.

" Deep " samples taken from the same lake, at the same spot and depth, will vary greatly in analytical results if the temperature of the water at the several dates of sampling should be markedly different, owing to the disturbing influence of vertical currents.

Again, suppose it is desired to determine whether or not the water of a river is so contaminated with upstream sewage as to be unfit for a town supply. A single analysis of the water taken from the site of the proposed intake would very possibly be valueless. Examinations of any real value in such cases should always be of a comparative nature, and should extend over sufficient time to embrace seasonal and other changes common to such sources.

Thus it is that the chemist must be in full possession of all the facts concerning the water which he is asked to examine, in order that his opinion as to its purity may be based upon the entire breadth of his past experience, for in no branch of chemical work are experience and good judgment better exercised than in the interpretation of a water-analysis.

A case such as this might arise: A water is condemned because of high chlorine. It is completely

sterilized by perfect filtration. After such filtration it contains as much chlorine as before but is then pronounced as safely potable. Note how important it would be to possess a knowledge of the history of the water in such an instance.

However faithfully the various laboratory tests may be applied to decide the question of the fitness or unfitness of a certain water for dietetic purposes, there is nothing upon which greater stress should be laid than a thorough personal knowledge of the surroundings of the source of supply. In other words, it is essential to make a careful and thorough " sanitary survey."

It was years ago laid down as a golden rule " never to pass judgment upon a water the history of which is not thoroughly known," and the nearer this maxim is lived up to to-day the fewer will be the mistakes in the reports issued.

A water-analysis is, for purposes of economy, rarely made complete. For ordinary drinking water the question is always asked " Is it wholesome? " To answer this the analysis of the mineral residue left upon evaporation is not usually required, so that much time and expense may be saved by simply reporting this as " total solids." On the other hand, analyses of mineral waters deal with this feature of the examination very largely, and usually to the

exclusion of those portions, such as " albuminoid ammonia," " required oxygen," etc., which are important in the sanitary analysis. The same may be said of the analyses of waters for boiler use.

CHAPTER II

CHEMICAL EXAMINATION OF WATER

DIRECTIONS FOR TAKING A WATER-SAMPLE

ONE-GALLON glass-stoppered bottles are to be used for sampling. They should be most carefully cleaned, their stoppers covered with tin foil and tied down with cloth. Upon being taken to the field they should be rinsed with the water to be sampled. Do not attempt to scour the interior of the neck by rubbing with either fingers or cloth. After thorough rinsing, fill the vessel to overflowing so as to displace the air, completely empty it and then collect the sample.

One gallon of water is more than is needed for the analysis, but it is wise to have sufficient to guard against accidental losses.

If the water is to be taken from a tap, let enough run to waste to empty the local lateral before sampling; if from a pump, pump enough to empty all the pump connections; if from a stream or lake, take the sample well out from the shore, and sink the stoppered sampling-vessel towards mid-depth before

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removing the stopper, so as to avoid both surface-scum and bottom mud.

In every case fill the bottle nearly full, leaving but a small space to allow for possible expansion, and close securely. Under no circumstances place sealing-wax upon the stopper, but tie the cloth firmly over the neck to hold the stopper in place. The ends of the string may be afterwards sealed if necessary.

Stoneware jugs are not admissible for collecting water-samples. They are hard to clean and some of the salt used for glazing may remain in the interior.

Bear in mind, throughout, that water-analysis deals with material present in very minute quantity, and that the least carelessness in collecting the sample must vitiate the results. Note the date of taking the sample, record the temperatures of both air and water and give as full a description as possible of the soil through or over which the water flows, together with the immediate sources of possible contamination.

Sketch the surroundings of the place of collection and give approximate distances of houses, privies, barns, and fertilized land, noting the general character and topography of the local watershed, in other words, make a careful sanitary survey.

Having secured the sample, the analysis should be begun at once, for the reason that water is liable to rapid changes in character during storage. For instance, the following analyses are of the same sample of water from the laboratory tap, drawn November 10, and allowed to stand in the sampling-bottle at ordinary room temperature:

	Nov. 10	Nov. 12	Nov. 13	Nov. 14	Nov. 15	Dec. 15
Free ammonia......	0.037	0.042	0.42	0.050	0.075	0.060
Albuminoid ammonia	0.220	0.178	0.191	0.175	0.155	0.205
Chlorine...........	4.5	....	....	....	....	....
N in nitrites........	trace	trace	trace	trace	trace	none
N in nitrates........	0.50	0.525	0.55	0.60	0.60	0.60
Required oxygen....	4.35	4.6	4.2	4.4	4.1	4.6
Total solids.........	140.	....	....	....	....	....

This water shows gradual oxidation of the nitrogen contents to nitrates, but on the whole is fairly stable. As showing, on the other hand, how rapid and how irregular the storage changes may at times be, the following analyses by Liversidge are given.*

These are, of course, exaggerated cases containing high ammonias, but they serve to point out the necessity of avoiding delay between the collection of the sample and the beginning of the analysis.

* *Chem. News,* lxxi. 249.

	HORSE-POND.		FISH-POND.		PEATY WATER.	
	Free Ammonia.	Albuminoid Ammonia.	Free Ammonia.	Albuminoid Ammonia.	Free Ammonia.	Albuminoid Ammonia.
December 11.........	10.00	7.00	0.12	0.90	0.72	0.19
" 12.........	2.00	2.00	0.11	0.92	1.12	0.04
" 13.........	8.00	4.00	0.16	1.04	1.12	0.13
" 15.........	7.00	4.00	0.16	1.03	1.08	0.12
" 16.........	6.00	2.00	0.38	0.69	0.03	0.04
" 19.........	5.00	2.00	0.52	0.56	0.02	0.03
" 20.........	4.00	1.00	0.70	0.38	0.01	0.01
" 21.........	2.00	0.50	0.90	0.30	....	....
January 8.........	0.50	0.25	1.38	0.06	....	....
" 10.........	0.07	0.07	1.50	0.04	....	....

Determination of dissolved gases should be done in the field.

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Not long since no small confusion existed, on account of the many ways in which the results of water-analyses were stated, but this difficulty is now nearly done away with by the more general acceptance of the recommendation that all results be given in *parts per million in weight.* This method has the advantage that a litre, or fraction thereof, of water having been operated upon, and the substances found having been determined in milligrammes, no long arithmetical calculations are required.

Of course the assumption is made that a litre of water weighs a kilogramme—a true enough statement for potable waters, but one capable of introducing error where mineral waters are dealt with whose specific gravities are appreciably above unity. In such a case the water to be analyzed is actually weighed, or else its weight is estimated from the known specific gravity and volume.

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Water should not be filtered before analysis. If sediment be present, it should be equally distributed by thorough shaking before measuring.

The reason for this is that a water-analysis should represent the water as the consumer uses it, and not in a condition improved by filtration.

Water-analysis cannot be conducted in a general laboratory, because many of the tests would be ruined by the fumes common to such a locality.

TURBIDITY

Turbidity was formerly reported in words, not figures. In order to express it in parts per million, the writer some years ago suggested the use of a standard suspension made by adding one gramme of exceedingly fine kaolin (obtained by eleutriation) to one litre of distilled water. Each c.c. of this preparation will contain one milligramme of suspended clay.

Whipple and Jackson improved this standard by substituting fine diatomaceous earth for the kaolin and later the U. S. Geological Survey introduced the use of Pear's Precipitated Fullers Earth, in which form it is used to-day. The earth is ignited, ground, passed through a 200-mesh sieve and weighed. One gramme being suspended in one litre of water gives a turbidity of 1000. Suitable dilutions of this standard suspension are kept in bottles of the size used for water samples and a series of " turbidities " is thereby obtained ready for instant use. A few crystals of mercuric chloride are added to each bottle to prevent organic growths.

Such a stock solution as the above, when diluted with nine times its volume of water, will permit of a platinum wire one millimetre in diameter being just visible at a depth of 100 millimetres below the water surface.

A turbidity-rod, prepared for the U. S. Geological Survey and based upon the above standard, is very convenient for use in the field.

The eye of the observer must be about 1.2 metres above the wire, and the reading should not be made in direct sunlight. The rod cannot be used for turbidities below seven. For turbidities over 500 the water should be diluted before the observation is made.*

* See Circular 8, Div. of Hydrography.

It must be noted that high color interferes with
the use of the turbidity-rod.   Thus the writer found
that the water of the Black River at Georgetown,
S. C., which showed a color of 162, gave a rod
reading of 31, while its true turbidity was only
five.

Any quickly subsiding material present should be

BERKEFELD FILTER.

classed as " sediment " rather than " turbidity."
To determine the same it would be best to decant the
water from above such deposit and then catch it
upon a weighed filter or in a Gooch crucible.

" Suspended " as distinguished from " dissolved "
material may be determined by estimating the solids,
as per page 23, both before and after passing the

water through a Berkefeld filter. The most convenient form of such filter is one illustrated on page 14.

ODOR AND TASTE

It is customary to report such odor and taste as a water may possess, although in the great majority of cases very little information is derived from such examination, because of the frequency of negative results. A good water may be possessed of a slight marshy odor, while one of extremely dangerous character may be limpid, tasteless, and odorless. The test is best applied both before and after heating the water nearly to the boiling-point, and after thorough shaking in each case.

Both taste and odor are sometimes very pronounced, as when such organisms as " Asterionella " are present in quantity. Fortunately, disease has never been traced to such occurrence, however objectionable the water may be from an æsthetic standpoint. Organisms of this character are revealed by a microscopical examination. See page 160.

TEMPERATURE

A cool water should, if possible, be supplied for public use, but studies of temperature are comparatively rare, for the sufficient reason that questions of much greater weight determine the selection of a

source of supply. The item of temperature is, however, well worthy of consideration. No small economy in the matter of the ice bill will follow the introduction of a cold water in place of one equally pure but warmer.

The advantage is especially noticeable in the poorer sections of the city.

For comparison: in June 1906, with the atmospheric temperature at 76° F., the water of Troy as delivered to the consumer was 66° and required further chilling to make it acceptable to the taste. At the same time the deep well supply of Ithaca, N. Y., stood at 56° and was agreeable for drinking without more cooling.

The extreme variation of temperature for Croton water, as delivered by the street hydrants in New York City, for the year 1894, was:

On February 24 . . . . 34° F.
On August 4 . . . . 76° F.

Should many temperature readings in deep water, as in a lake, be decided upon, no better device could be chosen for the work than the " thermophone," invented by Warren and Whipple. The following is clipped from a description issued by the makers, E. S. Ritchie & Sons, Brookline, Mass.:

" The thermophone is an electrical thermometer

of the resistance type. It is based upon the principle that the resistance of an electrical conductor changes with its temperature, and that the rate of change is different for different metals.

" The operation of taking a reading is as follows: Having connected the leading wires to the proper binding-posts of the indicator-box, the current is turned on and the telephone held to the ear. A buzzing sound in the telephone is found to increase or diminish according as the pointer is made to approach or recede from a certain section of the dial. By moving it back and forth a position may be found where the telephone is silent. When at this point, the hand indicates the temperature of the distant coil. Instruments of ordinary atmospheric range, i.e., from 15° to 115° F., may easily be read to 0.1° even by an inexperienced observer. With a smaller range, or with an instrument having a larger dial, a greater precision may be obtained.

" It is more sensitive than a mercurial or other expansion thermometer, because the rate of change of resistance per degree is greater than the rate of expansion of liquids or solids, and, moreover, slight changes in resistance may be more easily and accurately measured than slight changes in length or volume.

" It sets quicker than most mercurial thermome-

ters.   In obtaining the temperature of water of various depths one minute has been found to be sufficient time to allow for setting.

" It is independent of pressure." *

REACTION

The reaction of natural water is commonly slightly alkaline, although waters holding much free acid in solution, usually sulphuric, are by no means rare.

Determination of alkalinity.—Place 100 c.c. of the water in a casserole, and titrate with $N/10$ hydrochloric acid, using 1 c.c. methyl orange (0.5 gramme in one litre of distilled water) as an indicator.   Should the water be originally acid, make it slightly alkaline with a known amount of potassic hydroxide before titration.   It is convenient to report alkalinity as representing so many parts of $CaCO_3$ per million of water, and to note that such a form of result is quickly obtained by multiplying the number of c.c. of hydrochloric acid, used in the above titration, by fifty.

* The deepest sounding found on the Challenger expedition was in lat. 11° 24′ N., long. 143° 16′ E.   The depth was 4475 fathoms.

Temperature of bottom-water.............. 33.9° F.
        "   " surface-water.............. 80° F.

Most of the thermometers employed were crushed by the great pressure of five tons per square inch.

More recently the still greater depth of 5269 fathoms has been recorded.   See *Engineering News*, Nov. 22, 1900.

Acidity may be stated in the same terms, using a negative sign, or else as H_2SO_4.

Methyl orange is not a suitable indicator in presence of aluminum sulphate or of iron sulphate; therefore when examining the filtrate from a mechanical filter-plant it is better to substitute either lacmoid or the erythrosine indicator as recommended by the American Public Health Association.

Place 100 c.c. of water in a 250-c.c. glass-stoppered bottle. Add 1 c.c. of erythrosine (0.5 gramme of the sodium salt * in one litre of recently boiled distilled water) and 5 c.c. of chloroform. Shake after addition of each drop of the standard acid. The disappearance of the rose-color from the chloroform marks the end reaction.

This method is the more convenient of the two if the water under examination be high in color or turbidity.

Information is sometimes desired as to the cause of the alkalinity of a water. Is it due to hydroxides,† carbonates, or bicarbonates? To determine this point advantage is taken of the difference in action of two indicators towards these several compounds. Thus while hydroxides, carbonates, and bicarbonates react " alkaline " with methyl orange

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* $Na_2C_{20}H_6I_4O_5$.

† As in the effluents from softening plants.

or erythrosine, only the former two so react with phenolphthalein (5 grammes in one litre of fifty per cent alcohol). While, therefore, the "alkalinity" determined by the use of methyl orange or erythrosine might represent that produced by any single one of the three classes of substances above mentioned, or else by a mixture of carbonates and bicarbonates on the one hand or of carbonates and hydroxides on the other, the "alkalinity" as measured by phenolphthalein (using 1 c.c. of the alcohol solution noted above) could be due only to the hydroxides present plus one-half the normal carbonates.

The following conditions are possible:

1. If the alkalinity determined by the use of phenolphthalein (P) should be zero, then the alkalinity shown by methyl orange or erythrosine (M) would be due to bicarbonates alone.

2. If P should be equal to one-half M, then the alkalinity would be due to normal carbonates alone.

3. If P should be less than one-half M, then both carbonates and bicarbonates would be present and their quantities would be:

$$\text{Carbonates} = 2P,$$
$$\text{Bicarbonates} = M - 2P.$$

4. If P should be greater than one-half M, then bicarbonates would be absent and the alkalinity would be due to carbonates and hydroxides and their quantities would be:

$$\text{Carbonates} = 2(M - P),$$
$$\text{Hydroxides} = M - 2(M - P) = 2P - M.$$

COLOR

Hazen's platinum-cobalt color standard * is prepared as follows: Dissolve 1.246 grammes potassic platinic chloride (which amount contains 500 milligrammes of platinum) and 1 gramme cobalt chloride crystals in 100 c.c. strong HCl and dilute with distilled water to one litre. This solution has a color of 500.

By placing 1, 2, 3, 4, etc., c.c. of such solution in 50-c.c. Nessler tubes and diluting to the mark with distilled water, standard colors of 10, 20, 30, 40, etc., are obtained. A similar Nessler tube is filled with the water to be examined and comparison is directly made with the color standard.

A water possessing a color in excess of 70 should be diluted before reading the color, and then allowance for the amount of dilution should be made.

* *Am. Chem. J.*, xiv, 300.

Turbid waters should be filtered through a Berkefeld filter before reading the color.

The investigations of the Boston Water Board show that both iron and manganese often enter largely as a cause of color in water from the stagnant layer of a deep pond. In general, the color of a peaty surface water is mainly due to colloidal solution of organic material.*

AS TO ANALYTICAL " STANDARDS "

The establishment of hard-and-fast " standards for interpretation of analytical results " is simply an impossibility. Results which would be considered satisfactory for one locality might be entirely inadmissible in another. Local standards are the proper ones by which to be guided, and it is to be regretted that local " normals " are not more frequently found on record.

For New York and New England the information is more full, as is instanced by the fine charts of " normal chlorine " prepared for those States.†

Following the description of each analytical process

* An excellent paper by Mrs. Ellen H. Richards on " The Coloring-matter of Natural Waters " is published in *J. Am. Chem. Soc.*, January, 1896. See also " The Nature of Color in Water," J. N. E. Water Works Assoc., March, 1917.

† See Water-supply and Irrigation Paper, No. 144, U. S. Geol. Survey.

to be given hereafter there will be found a paragraph headed " Comparates," but the expression must not be permitted to mislead. The author's intention is simply to place before the reader sundry data and the opinions of various authorities, and he absolutely disclaims any desire to set boundaries to the free use of the analyst's good judgment.

TOTAL SOLIDS

Source.—Material dissolved or suspended in water is naturally derived from the strata through which the water passes, or the surface over which it flows. Thus are obtained waters of all degrees of hardness (see " Hardness ") and of great variety of color and turbidity.

Determination.—Thoroughly shake the vessel containing the sample and then measure out 100 c.c. of the unfiltered water by means of a pipette into a weighed platinum dish.

Evaporate to dryness on the water-bath, being careful to place a filter-paper between the dish and the water in the bath in order to prevent any deposit of impurities on the under side of the dish. (A better plan is to make use of a porcelain water-bath filled with distilled water.) When dry, place the dish and contents in an air-bath and maintain the temperature at 105° C. for half an hour. Cool in a desic-

cator and weigh. Replace in the air-bath and repeat
the weighing at intervals of half an hour until a
constant weight be obtained. The final weight,
less the known weight of the dish, will give the
amount of total solids. This weight multiplied by
ten will give the weight of solids per litre of water,
which, expressed in milligrammes, will represent
parts per million.

Should much $MgCl_2$ be in the water, add a known
amount of Na_2CO_3 before evaporation, and allow
for such addition in the final weighing. Otherwise
there will be loss due to the decomposition of the
$MgCl_2$.

$$MgCl_2 + 2H_2O = Mg(OH)_2 + 2HCl.$$

The " *loss on ignition* " is obtained by gradually
raising the dish and its contents to redness and
reweighing after cooling in a desiccator.

It is important to note that while no quantitative
results of much value are to be expected from the
ignition in question, yet considerable insight may
often be obtained as to the character of the water
by observing the intensity of the charring and the
presence or absence of fumes.

As Dr. Smart says: " The blackening during the
process is of more interest than the mere loss of
weight. No matter how few parts are lost, if the

lining of the capsule blackens all over and the carbon is afterward dissipated with difficulty, the water is to be viewed as suspicious.   What are called ' peaty ' waters here constitute the exception." *

Angus Smith pointed out that " in water containing nitrates and nitrites no organic matter would be apparent on burning unless more should be present than these salts could oxidize "—a fact always to be borne in mind.

If it be desirable to distinguish between " suspended " and " dissolved " solids, the latter may be determined by evaporating the water after passing through a Berkefeld filter, and by subtracting such value from the " total solids " a knowledge of the amount of " suspended solids " is secured.

Comparates.†

Average in sundry surface-waters known to be pure					74
"	"	"	"	polluted	194
"	"	ground-waters	"	pure	144
"	"	"	"	polluted	642

These averages are really of but small sanitary value, for the reason that a polluted water may be low in total solids, or *vice versa*, according to the character of the soil through or over which the water flows.

* Report Nat. Board of Health, 1880.
† See page 23.

The Rivers Pollution Commission of Great Britain gives as averages out of 589 samples of unpolluted waters analyzed for total solids:

> Rain...................... 29.5
> Upland surface.............. 96.7
> Deep well.................. 432.8
> Spring..................... 282.0

Colby considers* that water containing over 306 of carbonate of sodium or of common salt is not suitable for irrigation. He believes also that for drinking purposes the soluble salts should aggregate not over 680.

HARDNESS

Before entering into the question of quantitative estimation, let it be premised here that " hardness " may be classified under two heads, viz., " permanent " and " temporary," and many samples of water possess them both. The former is occasioned by the presence of calcium sulphate, and other soluble salts of calcium and magnesium held in solution by the solvent action of the water itself; such a water cannot be materially softened by boiling under ordinary pressure.

" Temporary " hardness is caused by carbonates

* Col. Agric. Expr. Sta., 1903.

of calcium and magnesium held in solution by union
with carbonic acid present in the water. Boiling
such a water breaks up the union and expels the
carbonic acid, whereupon the bulk of the salts
separate from solution. Not all of them, however,
as water has power to retain slight amounts of
these two normal carbonates in solution.

It may be considered in short that the calcium or
magnesium is present as a soluble bicarbonate which
breaks upon boiling into water, carbonic-acid gas
and insoluble normal carbonate. In this connection
A. H. Allen holds that it is not necessary to assume
the existence of calcium bicarbonate in order to
account for the solubility of calcium carbonate.
One water which he examined evolved very small
quantities of carbon dioxide on boiling, and yet the
precipitated calcium carbonate was large in amount.
He considers it " probable that calcium carbonate is
capable of existing in a soluble colloid condition,
changing, on boiling the liquid, to the ordinary in-
soluble modification." *

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" *Permanent hardness* " is determined by Hehner's
method.† The measured water is boiled to dryness

* *J. Soc. Chem. Ind.*, vii. 801.
† *Analyst,* viii. 77.

with a known excess of Na_2CO_3. Recently boiled distilled water is added. Precipitated $CaCO_3$ is filtered off, and the Na_2CO_3 remaining in the filtrate is determined by titration with standard acid, using methyl-orange or erythrosine as an indicator. The loss in Na_2CO_3 is calculated to a corresponding amount of $CaSO_4$.

" *Temporary hardness* " is often equal to the " alkalinity," previously determined.   See page 18.

The latter may be the larger of the two, however, as for instance in the case of the presence of sodium or potassium carbonates or bicarbonates.

A more accurate knowledge of the amount of " temporary hardness " is secured by determining the alkalinity as usual, and then again determining it after precipitating the carbonates of Ca and Mg by boiling, filtering, cooling and restoring volume lost by evaporation.

The only useful purpose served by a determination of " temporary hardness " is to allow of a prediction being made as to whether such scale as may be formed by the use of the water for steam purposes will be friable or dense in character.
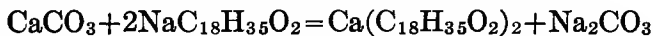
So far as action on soap is concerned the " total hardness " is the item of importance.

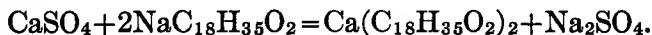" *Total hardness* " is most satisfactorily deter-

mined by the usual quantitative methods for estimating calcium and magnesium.

Soap-consuming Power.—Whether a water be permanently or temporarily hard it will destroy soap, and such destruction is often assumed to measure the total hardness. The assumption is an error, however, for water alone will decompose soap, and the presence of carbon dioxide in solution will increase the loss of soap to a notable degree. In short the " soap test " has shown itself unsatisfactory except for the determination of what its name suggests, " the soap-consuming power of the water."

Ordinary hard soap is somewhat complex in structure, but for practical purposes we may consider it to consist of sodium stearate, $NaC_{18}H_{35}O_2$. This salt, coming in contact with the calcium carbonate or sulphate contained in a hard water, is immediately decomposed, with formation of insoluble calcium stearate according to the following equations:

$$CaCO_3 + 2NaC_{18}H_{35}O_2 = Ca(C_{18}H_{35}O_2)_2 + Na_2CO_3$$

or

$$CaSO_4 + 2NaC_{18}H_{35}O_2 = Ca(C_{18}H_{35}O_2)_2 + Na_2SO_4.$$

Of course none of the soap can be depended upon for detergent purposes until all the calcium salts present have been thus provided for, hence the

enormous waste resulting from the use of some waters may readily be imagined.*

What has been said with reference to the effect of salts of calcium upon soap applies likewise to the salts of magnesium.

In undertaking the estimation of soap-consuming power or " soap hardness " advantage is taken of the reaction above stated. A solution of soap of known strength is prepared, and is then added little by little to a given quantity of the water to be examined, until a permanent lather is formed, whereupon, from the known quantity of soap solution used, the amount of " hardness " present may be calculated.

This soap test, commonly known as Clark's, is not accurate, and is in some respects unscientific; but it is not without value, especially in a locality such as Troy, N. Y., where the enormous laundries use soap by the ton.

Soap Solution.—From a new cake of Castile (Syria)

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* " While no exact rule can be given for estimating the increased expense to a community caused by the use of hard water, in general it may be said (*Eng. News*, January 31, 1885) that each grain of carbonate of lime per gallon of water causes an increased expenditure of 2 ounces of soap per 100 gallons of water. The Southampton water contains about 18 grains of lime and magnesian salts per gallon. With such hard water it is probable that the increased expense for soap in a household of five persons would amount to at least $5 to $10 yearly; hence the inhabitants could afford to pay a higher water-rate by the amount of this difference for a soft-water supply." (*Engineering News*, April 16 1892.)

soap scrape ten grammes of shavings.   Dissolve them in one litre of dilute alcohol ($\frac{1}{2}$ water).   If not clear, filter, and keep tightly stoppered.   Sodium oleate may be used in place of soap.

Calcium Chloride Solution.—Carefully weigh out one gramme of pure $CaCO_3$.   Dissolve in a little HCl.   Evaporate to dryness.   Add a little distilled water and again evaporate to dryness to expel the excess of acid.   Dissolve the residue in distilled water and dilute to one litre.   Each cubic centimetre of this solution will contain an amount of calcium chloride equivalent to one milligramme of $CaCO_3$.

Standardizing the Soap Solution.—Place 10 c.c. of the calcium chloride solution in an eight-ounce glass-stoppered bottle, make the volume up to 100 c.c. with recently boiled but cooled distilled water, and run in the prepared soap solution from a burette, little by little (shaking after each addition), until a lather be formed which persists for five minutes.   Even when the amount of soap solution required is approximately known, never add more than half a cubic centimetre at once, and never fail to shake after such addition.*

Observation of the lather should be made with the bottle lying on its side.

* See *Chem. News*, August, 1886.

Note the amount of soap solution used. Now repeat the experiment, using 100 c.c. of pure water only (no calcium chloride solution), and again note the amount of soap solution required. This second reading will give the amount of soap solution (no inconsiderable quantity) used up by the 100 c.c. pure water, and by subtracting the same from the reading obtained in the first instance knowledge will be reached of the quantity of soap required for the calcium salt alone. Estimate now the value of 1 c.c. soap solution in terms of calcium carbonate and record the result on the bottle. Perhaps an example would be in keeping:

8.2 soap solution are required for 10 c.c. calcium chloride solution+90 c.c. water.

0.6 c.c. soap solution are required for 100 c.c. water.

Hence

7.6 c.c. soap solution are required for 10 mg. $CaCO_3$.

Hence

1 c.c. soap solution corresponds to 1.316 mg. $CaCO_3$.

Always place the date of standardizing on the bottle, and re-standardize frequently, as the soap solution is not permanent.

Determination.—Place 100 c.c. of the water in the eight-ounce bottle, run in the standard soap solution

in the manner already stated, read off the amount required to produce the lather, multiply by the known value for 1 c.c. soap solution, multiply this again by ten, and there will be obtained the " soap hardness " expressed as so many parts of $CaCO_3$ per million of water.

It was formerly customary to report hardness in " degrees " rather than parts per million, but the difficulty of deciding which of the several systems of degrees was referred to provoked so much confusion that a change was made to the present simpler mode of expression.*

Magnesium salts decompose soap rather slowly; therefore do not conclude that the end point has been reached until after the lather has been observed to readily return upon shaking after a few minutes' waiting.

If the " hardness " due to salts of magnesia be required separately, shake the water up with a little solid ammonium oxalate, filter off the precipitated calcium oxalate on a dry filter, and determine the " hardness " in the filtrate.

---

* In England the Clark scale is still in use. Each degree corresponds to one grain of $CaCO_3$ per imperial gallon of water, i.e., one part in seventy thousand. Water below 6 degrees is considered soft. In France one degree corresponds to one part of $CaCO_3$ per 100,000 parts of water. In Germany one degree corresponds to one part of CaO per 100,000 of water.

When a water is so hard as to require a greater amount of soap solution for the 100 c.c. of the water than suffices to saponify 23 mg. $CaCO_3$, better results are obtained by diluting the water with an equal bulk (or more, if necessary) of distilled water, inasmuch as too heavy a precipitate of the calcium stearate appears to interfere with the proper lathering. Of course the influence of the additional quantity of water must be allowed for.

For constant results the hardness of a water should be taken at a temperature of 15° C.*

Comparates.—The average hardness of good waters as given by the British Rivers Pollution Commission stands:

Rain........................	3
Upland surface.............	54
Deep well....	250
Spring.....	185
Wanklyn allows..	575

Middleton thinks that from 40 to 70 parts per million of hardness will give the most satisfactory results generally, and that the limit of hardness for public supply should be placed at 350 parts per million.†

* *J. Chem. Soc.*, lxiv. ii, 347.
† " Water-supply," page 17.

Pearmain and Moor* consider that "a greater hardness than 300 is undesirable from the hygienic standpoint."

They classify as follows:

Very soft......	30 to 50 per million
Moderate......	50 " 100 "
Hard.........	100 " 300 "
Very hard.....	above 300 "

The rating of water as "hard" or "soft" is very often a matter of local preference.

Thus the writer has encountered cases of complaint from people using a water of as low a hardness as 30 parts per million; and has heard others described as of "good quality for boiler and laundry uses" a water which ran 66 in hardness. After wide inquiry among industrial water users the author has concluded to classify waters (in the Eastern states) as "soft" which do not exceed 50 in hardness; to call those "hard" which exceed 100; and to consider the intermediate values as a sort of neutral ground where local conditions and preferences shall govern.

CHLORINE AS CHLORIDE

Water is never found free from chloride, yet, notwithstanding its constant presence, there is hardly

* "Water-analysis," page 48.

a factor in the sum total of water-analysis to-
wards which attention is more quickly turned, or
regarding which there is closer scrutiny.

In most instances a chloride is present in the form
of common salt, washed from the air or soil, or
added as one of the constituents of sewage. Salt
itself is, of course, unobjectionable in the quan-
tity usually present, but, it being so largely used
in our food, there is always warrant for suspecting
sewage contamination where the figures for chloride
run high.

True it is that those figures are at times mislead-
ing, but they, like other data in water-analysis,
must be considered with judgment, and due weight
be accorded the character of local surroundings.

If the district whence a water comes be naturally
rich in salt, as in the case of Central New York, such
fact must be borne in mind when formulating an
opinion as to quality. Comparison should be made
with a local water, of the same general character,
known to be pure; and for that purpose State maps,
such as those issued for New York and New Eng-
land, are most valuable, and their construction is
well worth the expenditure of public money.

The normal chlorine maps for Massachusetts and
Connecticut are here given as illustrations. More
complete " isochlor charts " will be found in Water-

supply and Irrigation Paper No. 144, U. S. Geol. Survey.

The influence of the sea upon the " normal chlorine " of these States is made apparent by the charts.

Such influence is naturally marked in an insular country like England.

" Normal chlorine " of a district is the amount of chlorine occurring in the unpolluted waters thereof. Ponds are the best waters to use for its determination. The " normal chlorine " for deep-seated waters should be placed in a separate class.

Variation in the chloride-contents of rain-water always occurs inland, although not to the same degree as upon the coast. For instance, the mixed monthly rain and melted snow near Troy, N. Y., during 1896, contained the following amounts of chlorine as chloride:

January	2.50	per million
February	1.07	"
March	1.55	"
April	0.75	"
May	1.25	"
June	1.15	"
July	1.05	"
August	2.00	"

September..........	0.60	per million
October...........	3.00	"
November.........	2.25	"
December.........	2.50	"
Mean...........	1.64	"

While not strictly city rain-waters, the Troy samples were doubtless affected by the neighborhood of the city.

Although varying with the locality, yet the amount of common salt lifted from the ocean in spray and subsequently dropped upon the land in rain is always noteworthy. Professor Clark reports the Rothamsted, England, figures as 24 pounds per acre per annum.

Ground-water is more directly influenced than rain-water by the presence of human habitation. Thus the Massachusetts Board of Health (1890 [1], 680) found that twenty persons per square mile will add on the average, 0.1 part per million of chlorine as chloride to the water flowing from such district.

The determination of chloride in water is extremely simple. It depends upon the fact that if to a solution of a chloride which has been colored yellow by addition of a little potassium chromate

a solution of silver nitrate be added, white silver chloride will be produced until the last trace of chlorine be disposed of, whereupon red silver chromate will begin to appear.

The reagents required are:

Standard Silver Nitrate Solution.—Prepared by dissolving 4.8022 grammes of crystallized silver nitrate in one litre of water. Each cubic centimetre of such a solution is of a strength sufficient to precipitate one milligramme of chlorine. In common with all other reagents for water-analysis, it should be kept in bottles having caps covering the stoppers, such as are used for volatile liquids. Check this solution against the *Standard Sodium Chloride Solution,* page 54.

Potassium Chromate, Indicator. — Dissolve 2 grammes of the pure salt in 100 c.c. of distilled water. Should the reagent not be perfectly free of chloride add a little silver nitrate until red silver chromate begins to precipitate; let the precipitate settle and decant the liquid for use.

Determination.—One hundred c.c. of the water to be examined are placed in a large Nessler tube; 1 c.c. of the potassium chromate solution is added, and mixed by the use of a glass plunger. (See footnote page 48.) The standard silver solution is then run in from a burette, until the red tint of the silver

chromate just appears. From the known amount of silver solution used the amount of chlorine present is obtained, and this, multiplied by ten, will give the chlorine in milligrammes per litre or parts per million.

To determine with accuracy the first appearance of the red tint, it is best to make the examination in yellow light, either by the use of a photographic " dark room " lantern with a front of yellow glass, or by simply looking through a plate of such glass. Reflection from a porcelain tile throws the light through the length of the Nessler tube, and side light is cut off by a black screen. The writer uses a box painted black on the inside and fitted with a top of yellow glass.

A second tube of the water, also colored with potassium chromate, should be provided in order that the formation of the red tint in the vessel operated upon may be, by comparison, more readily detected.

Acid waters should be neutralized with Na_2CO_3 before beginning the chloride determination. On the other hand, should a water's alkalinity be due to normal carbonates or to hydroxides, as in the case of an overdose of lime in the softening process, it should be neutralized with H_2SO_4, any excess of which is in turn neutralized with Na_2CO_3. In all
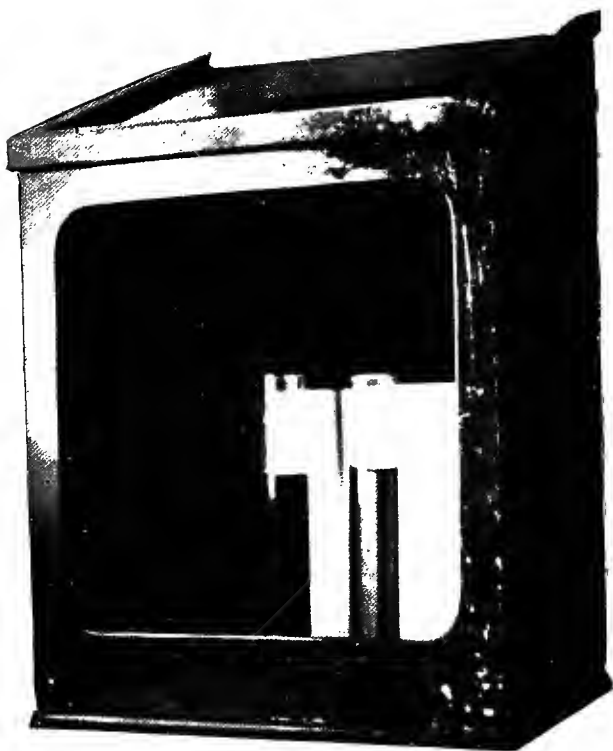
DEVICE FOR READING CHLORINE IN CHLORIDES.

of these cases the indicator used should be phenol-phthalein.

Many waters possess such deep color, or such turbidity, as to interfere with proper titration; under such circumstances it is best to shake 500 c.c. of the water with 3 c.c. recently precipitated and washed aluminum hydroxide and then filter it, or allow it to stand twenty-four hours in a tall glass cylinder. The coloring matter or turbidity is thus removed, and the water cleared for use.

With waters high in chloride it is often very difficult to decide just when the red color begins to appear, for the reason that it is hard to compare the clear yellow liquid of the camparison-vessel with one which has become turbid from precipitation of silver chloride.

In such a case it is well to roughly determine the chloride present and then to make a second determination, using for comparison 100 c.c. of the water to which has been added not only the chromate indicator, but also an amount of silver nitrate solution just short of that necessary to satisfy the chloride present.

By these means the eye is greatly aided in noting the appearance of red tint, for in respect of turbidity both vessels are practically alike.

Should a volume of water smaller than 100 c.c.

be taken because of the high chloride present the same must be diluted with distilled water to 100 c.c. before making the determination.

Circumstances sometimes demand, when the amount of chloride is very low, that a larger volume than 100 c.c. of the water be employed. For such purpose it is best to place the measured quantity of water in a porcelain casserole and to make it slightly alkaline with Na_2CO_3 before concentration. After reduction of the volume to 100 c.c. the Na_2CO_3 is neutralized with H_2SO_4, using phenolphthalein as an indicator, and the process is continued as already described.

It is important that the same volume (100 c.c.) be always secured before running in the silver nitrate solution; therefore distilled water must be added if the concentration should have been carried too far.

The porcelain of the dish does not interfere with this determination, but it is very important to carefully scrub and wash down its sides after evaporation.

High chloride often causes confusion in reading the end point. After reading the burette a false end point must be always guarded against by the addition of several extra drops of the silver solution, which overdose will produce a marked red coloration if the true end point be already reached.

Although a water very high in chloride might be diluted before applying the method described, yet better results would be secured by employing

Volhard's Process, as follows: Take 100 c.c. of the water, or a larger bulk concentrated to that volume after addition of a little sodium carbonate. Add 3 or 4 c.c. ferric alum solution, and 2 c.c. strong nitric acid (free from nitrous fumes). Add *small*** excess of the standard silver nitrate solution. Filter, wash, and titrate the excess of silver with standard KCNS solution. The silver solution used up by the chlorine can be calculated. Do not omit to filter, as it avoids risk of action between the AgCl and Fe(CNS)$_3$.

Saline mineral waters require gravimetric methods. About 400 parts per million of NaCl will produce taste.

Comparates†

Average in sundry surface-waters known to be pure	. . . .	3.57
" " " " polluted	. . . . .	6.06
" " ground-waters " pure	. . . .	3.2
" " " " polluted	. . . . .	91.7

The Rivers Pollution Commission reports the average amount of chlorine in 589 samples of unpolluted English waters as follows:

* For objection to large excess, see *J. Am. Chem. Soc.*, xxxiii, 1344.
† See also p. 86.

Rain....................... 8.22
Upland surface.............. 11.3
Deep well................... 51.1
Spring...................... 24.9

(Great Britain being an island, chlorine would naturally run high.)

Ordinary sewage, about 110 to 160.

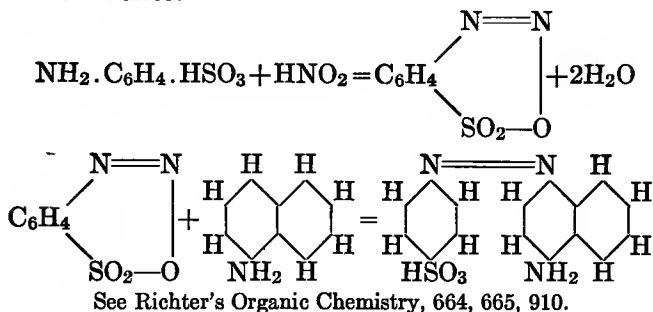Human urine (average of 24 samples), 5872.

NITROGEN AS NITRITES

Broadly stated, the presence of nitrites, especially in shallow well water, is to be considered as unfavorable. They are at times due to a harmless reduction of nitrates, as by the iron piping of a well, but more commonly they are an *in transitu* product of the oxidation of the organic nitrogen derived from a source of contamination.

In either case it is necessary to estimate their quantity.

———

Of the several methods used of late for the determination of nitrites the second one suggested by Griess seems to be the most deserving of favor. It depends in principle upon the red coloration (" azobenzol-naphthylamine sulphonic acid ") produced whenever "sulphonic acid" and "naphthyla-

mine hydrochloride " are added to an acidified solution of nitrite.

$$NH_2.C_6H_4.HSO_3 + HNO_2 = C_6H_4 \begin{array}{c} N\!=\!\!=\!N \\ \diagup \qquad \Big| \\ SO_2\!-\!O \end{array} + 2H_2O$$

$$C_6H_4 \begin{array}{c} N\!=\!\!=\!N \\ \diagup \qquad \Big| \\ SO_2\!-\!O \end{array} + \begin{array}{c} H \quad H \\ H\diagup\!\diagdown\!H \\ \diagdown\!\diagup \\ H\diagdown\!\diagup H \\ NH_2 \; H \end{array} = \begin{array}{c} N\!=\!\!=\!N \quad H \\ H\diagup\!\diagdown\!H \quad H\diagup\!\diagdown\!H \\ \diagdown\!\diagup \qquad \diagdown\!\diagup \\ H\diagdown\!\diagup H \quad H\diagdown\!\diagup H \\ HSO_3 \qquad NH_2 \; H \end{array}$$

See Richter's Organic Chemistry, 664, 665, 910.

The test is exceedingly delicate and is capable of distinguishing one part of nitrogen as nitrous acid in one thousand million parts of water.

The reagents required are prepared as follows:

Sulphanilic Acid.—Dissolve 8 grammes of the salt in 1 litre of water containing 50 c.c. concentrated HCl.

Naphthylamine Hydrochloride.— Dissolve 5 grammes of the salt in 1 litre of water containing 8 c.c. concentrated HCl.

Standard Solution of Sodium Nitrite. — Sodium nitrite may be bought, but its purity is always to be questioned, and moreover it is too deliquescent a salt to be weighed with ease and accuracy. It is better, therefore, to prepare the silver salt, which may be readily handled, and from it the solution required may be made.

To a cold solution of commercial sodium or potassium nitrite add a solution of silver nitrate as long as a precipitate appears. Decant the liquid and thoroughly wash the precipitate with cold water. Dissolve in boiling water. Concentrate and crystallize the silver nitrite from the hot solution. Dry in the dark at ordinary temperature (using vacuum is better) and keep it in a black bottle.

Weigh out 0.22 gramme of the dry silver nitrite. Dissolve in hot water. Decompose with slight excess of sodium chloride, cool if necessary, and dilute to one litre. Allow the precipitated silver chloride to settle, remove 5 c.c. of the clear solution, and dilute the same to one litre. This second dilution (which is the standard solution to be used) will contain an amount of nitrite per cubic centimetre equivalent to 0.0001 milligramme of nitrogen.

Determination.—In order to undertake the determination of nitrites place 100 c.c. of the water to be examined (decolorized with aluminum hydroxide if necessary) in a Nessler tube. Add 2 c.c. of the sulphanilic acid solution, followed by 2 c.c. of the solution of hydrochloride of naphthylamine, mix,* cover with a watch-glass, and set aside for thirty

* To accomplish this mixing it is best to use a stout glass rod ten inches long, at one end of which is fused a cross, composed of two pieces of glass rod ¾ inch in length. The mixer is used as a plunger.

minutes. Prepare at the same time other Nessler tubes containing known amounts of the standard solution of sodium nitrite and diluted to the 100-c.c. mark with nitrite-free distilled water, adding the reagents as above. At the end of the time stated (thirty minutes) examine the depth of the pink color formed, and by comparing the unknown with the known an accurate determination of the amount of nitrogen present as nitrites may be made.

If much gas be burning in the room, nitrites will be in the atmosphere. Hence cover the tubes or remove them from the room during the half-hour interval before reading.

The error due to the presence of burning lamps is often much greater than is suspected.

Comparates.—In a report upon the presence of nitrites in eighteen " natural waters, believed from actual use to be of good, wholesome character," and collected from every variety of source, Mallet's determinations show an average of 0.0135 part nitrogen as nitrites per million parts of water. The average, by the same investigator, for nineteen waters "which there seems to be fair ground for believing have actually caused disease " is 0.0403 part per million.

The author's experience has been that the average amount of nitrites found in good waters is very much less than the value given by Mallet.

The absence of nitrites proves nothing. The author has had a most foul cistern-water for analysis which showed but a trace of nitrites and no nitrates, and yet the water was contaminated with the entire house-drainage and produced serious illness.

Average in sundry surface-waters known to be pure........	**0.000**
" " " " polluted.....	**0.006**
" " ground-waters " pure........	**0.000**
" " " " polluted.....	**0.003**

See also page 86.

NITROGEN AS NITRATES

Nitrates present in water are but an additional step in the oxidation of nitrogenous organic matter.

They are more liable to indicate putrefaction of animal rather than of vegetable tissue, not only because of the greater quantity of nitrogen present in the former, but also on account of its more ready decomposition.

Stoddart claims that " natural waters can, at most, obtain but from 1/10 to 2/10 grain of nitrogen as nitrates per imperial gallon (1.43 to 2.86 per million) from sources other than animal matter; and practically the whole of the nitrogen of sewage may be oxidized into nitric acid without diminishing the risk involved in drinking it."

" The proposal to consider a water safe so soon as the nitrogen has assumed the oxidized condition,

irrespective of the quantity that may be present, is entirely irrational." *

The above warning is really unnecessary, for no one would risk an opinion based upon chemical data alone.

Results derived from a bacteriological examination together with knowledge obtained from a sanitary survey would supplement the chemical analysis and guard against an error of judgment.

Rain-water washes a very considerable amount of nitric nitrogen from the atmosphere; thus an official report gives the following amounts of nitrogen as nitrates in sundry rain-waters, showing at the same time the tendency of neighboring towns to increase this item:

	Parts per Million.
England, interior	0.19
" cities	0.22
Scotland, near the coast	0.11
" interior	0.08
" cities	0.30
" Glasgow	0.63
Montsouris, Paris, average of 18 years	0.73

Nitrogen in the soil is increased by the fixing of atmospheric nitrogen through the agency of the roots of leguminous plants, such as peas, the process being aided by bacterial action.

* *Analyst,* xviii, 293.

An interesting experiment to show this was recently made in France. Peas were grown in a closed space, and the nitrogen lost by the confined air was found equal to what was gained by the ground and plants. No such fixation of nitrogen was obtained when the soil was previously sterilized.

Such fixed nitrogen eventually enters the ground-water, and a knowledge of the local " normal " for nitric nitrogen is consequently of advantage when studying the domestic well-waters of a neighborhood.

Surface- and shallow ground-waters of good quality are low in nitrates, for the reason that such material is quickly absorbed by growing vegetation.

After having tried many ways for the determination of " nitrates " in potable water the writer has adopted a modification of the old so-called " picric acid method," as giving, on the whole, the greatest satisfaction.

Phenol disulphonic acid is made by the action of phenol on sulphuric acid:

$$C_6H_5OH + 2H_2SO_4 = C_6H_3(OH)(SO_3H)_2 + 2H_2O.$$

This reagent, reacting with nitric acid, produces an intense yellow color upon addition of ammonium hydroxide.*

* See *Analyst*, x, 200; also a discussion by Chamot, J. Am. Chem. Soc., xxxi, 922.

The intensity of this yellow color, produced in the water under examination, is compared with standard colors of known strength, and the quantity of nitrate present is thus determined.

The presence of high chlorides interferes with this process, resulting in readings decidedly lower than the truth. In such a case the addition of sodium chloride to the comparison standards will rectify the difficulty.

The " chloride " in the water under examination having been previously determined, an appropriate volume of standardized sodium chloride solution is added to each of the standard nitrate comparison solutions. Thus the water to be examined, and the nitrate solutions with which it is compared, all contain the same quantity of chlorine. The results are satisfactory. If the chlorine be below thirty parts per million it does not materially interfere with the nitrate determination.

The removal of chlorides, before testing for nitrates, may be accomplished by nearly neutralizing the alkalinity with H_2SO_4 and then adding Ag_2SO_4 solution (not to excess), filtering and using the filtrate to determine nitrates. This procedure is recommended by " Standard Methods."

The solutions required for determination of nitrates are:

Phenol disulphonic acid.—

Sulphuric acid, pure and concentrated. 370 grammes
Pure phenol...................... 30   "

Place these in a flask and keep the same sur-
rounded by boiling water for six hours. Disul-
phonic, instead of monosulphonic acid, is thus
produced by the prolonged high temperature, and
reacts readily upon the nitrate.[*]

Standard Potassium-nitrate Solution. — Dissolve
0.7221 gramme pure KNO_3 in 1 litre distilled water.
Evaporate 10 c.c. of this solution just to dryness on
the water-bath. Thoroughly moisten with 2 c.c. of
the phenol-sulphonic acid and dilute to 1 litre.
Each cubic centimetre of this solution will cor-
respond to 0.001 milligramme of nitric nitrogen.[†]

Standard Sodium-chloride Solution. — Dissolve
1.6479 grammes pure fused NaCl in 1 litre distilled
water. Each cubic centimetre will contain 1 milli-
gramme of chlorine.

Standard Silver-sulphate Solution.—Dissolve 4.4
grammes Ag_2SO_4 in one litre of distilled water.
Each c.c. of this solution corresponds to one milli-
gramme of chlorine.

Determination.—Take 100 c.c. (or less, according

[*] " Sanitary Investigation of the Illinois River," page 9.
[†] *J. Infectious Diseases*, May, 1905.

to nitrate-contents) of the water that has been decolorized as per page 43. Remove chlorides with Ag_2SO_4 if necessary and evaporate to dryness on the water-bath. Thoroughly moisten the residue with 2 c.c. of the phenol-sulphonic acid. Dilute with water and make alkaline with ammonium hydroxide. Pour into a 100-c.c. Nessler tube. Dilute with water to the mark, mix and compare the depth of color with those produced by diluting different amounts of the standard potassium nitrate solution to 100 c.c., each such comparison-tube having 5 c.c. strong ammonic hydroxide added before filling to the mark. In case the chloride be high there should be also added to each tube an amount of standard sodium-chloride solution sufficient to correspond with the amount of chloride previously found to exist in the water, unless the chloride be removed by the Ag_2SO_4 method.

The evaporations are best made in deep evaporating-dishes of glass which easily hold 100 c.c. After dryness is reached the dish, with its contents, should be at once removed from the water-bath.

The writer prefers evaporating dishes of glass rather than porcelain for the reason that the residue to be treated is more easily seen.

In order to economize time, when dealing with

waters low in chlorine, it is convenient to make use of a series of standard " nitrate color solutions."

They keep their normal strengths of color quite well, but should not be trusted after having been a few weeks in stock.

Before evaporating for the nitrate determination it is best to remove turbidity and to decolorize the water with aluminum hydroxide as under " Chlorine" (see page 43).

Comparates *

Average in sundry surface-waters known to be		pure.......	0.139
"	"	"	"	polluted....	0.749
"	"	ground-waters	"	pure.......	1.4
"	"	"	"	polluted....	11.9

The Rivers Pollution Commission gives the following averages from 589 unpolluted English waters for nitrogen as nitrites and nitrates *together:*

Rain.................... .. 0.03
Upland surface... .... 0.09
Deep well 4.95
Spring................. ... 3.83

As illustrating how widely the nitrates may vary in deep wells of good character the following list is taken from the *Analyst,* xx, 84:

* See also page 86.

Depth of Well in Feet.		N as Nitrate
200.	Stratford	0.00
200.	Wimbledon	0.43
490.	Chatham	6.85
900.	Southend	0.71
600.	Witham	6.43
160.	Mistley	0.71
430.	Braintree	0.28
305.	Colchester	0.00
400.	Norwich	11.43

It is frequently observed that deep waters have their nitrates entirely removed by the reducing action of the iron well-casing. Under such circumstances the nitrogen appears as high "free-ammonia."

Jamieson reports heavy nitrates in Connecticut well-waters, and notes that they produce pitting in boilers. He found in a well-water from the city of New Haven the nitrogen as nitrates as high as 41.3 parts per million. He also gives a list of twenty other well-waters running from 15.4 to 2 per million.

Fresh sewage is usually found entirely free of either nitrites or nitrates simply because the organic nitrogen present has had, as yet, no sufficient opportunity to become changed to the oxidized form. For instance, a sample of the sewage of Troy, N. Y., contained:

	Parts per Million.		Parts per Million.
Free ammonia	0.875	Chlorine	31
Albuminoïd ammonia	0.675	" Required oxygen "	89
Nitrogen as nitrates	none	Total residue	489
Nitrogen as nitrites	trace	Loss on ignition	315

A curious case of good water with very high " nitrates " came under the writer's observation. The water was from a deep rock-drilled well, which had been " torpedoed " by fifty pounds of nitro-glycerine. Note how important the " history of the case " was to a proper interpretation of the analytical results in this instance.

NITROGENOUS ORGANIC MATTER

It will be remembered that the "cycle of organic nitrogen " may be represented as starting with the nitrogen firmly bound in the organic molecules, whence through the operation of disintegrating agencies that portion which does not gasify passes into the structure of other complex but less stable compounds until towards the end of its course it appears as a constituent, first of ammonia, then of nitrites, and finally of nitrates; after which, through the availability of the last as plant-food, it again starts upon its organic career.

It is desirable for us to trace if we can the progress of the nitrogen from its start in fresh and stable organic material to its finish in the mineralized ni-

trate form; and to measure its quantity in the successive steps of organic decomposition and inorganic oxidation.

The most general method now employed for obtaining information as to the nitrogenous organic matter is Wanklyn's

Albuminoid-ammonia Process.—By the employment of this method a knowledge of the amount of " free ammonia " present is also obtained.

We may outline the process as follows: The "free ammonia " is distilled from a measured quantity of the water, and its amount is determined by what is known as Nessler's method, which will be described later. A strongly alkaline solution of potassium permanganate is then added to another portion of the water and the distillation is repeated. Nitrogenous organic matters are thereby broken up and the resulting ammonia (" albuminoid "), which distils over with the " free," is determined by the Nessler method in like maner as before. It must be noted that the so-called " albuminoid " ammonia does not exist ready formed in the water, but is a product of the decomposition of organic nitrogenous substances by the alkaline permanganate. The term is derived from the fact that albumen gives off ammonia in like manner when similarly treated.

The reagents necessary are:

Nessler's Reagent.—Dissolve 35 grammes potassium iodide (KI) in about 200 c.c. pure water. Add a saturated solution of mercuric chloride ($HgCl_2$) until a faint show of excess is indicated. Add 160 grammes solid potassium hydroxide (KOH). Dilute to one litre, and finally add a strong solution of mercuric chloride, little by little, until the red mercuric iodide just begins to be permanent. Do not filter from excess of mercuric iodide, but let the same settle to the bottom of the vessel. The finished reagent should have a pale straw color. It is improved by age.

Nessler's reagent will give a distinct brownish-yellow coloration with the most minute traces of ammonia or ammonium salts. If the quantity of ammonia be at all considerable, a brown precipitate will appear. The reaction in case of either precipitate or coloration will be

$$2(2KI,HgI_2) + NH_3 + 3KOH = \overline{NH_2HgOHgI} \\ + 7KI + 2H_2O.$$
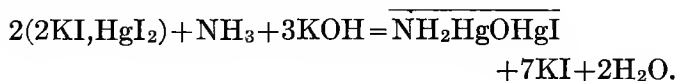
Ammonia-free Water.—This must be prepared with great care, in a room free from the usual laboratory fumes. In short, as has been already said, the entire examination of potable water should be undertaken in a locality other than a general working laboratory. A suitable retort for this purpose is of copper,

five gallons in size, and with a tin condensing-worm. Fill it with good spring-water, add a few crystals of potassic permanganate, distil, collect distillate in 50-c.c. Nessler tubes, and to each successive tubeful so collected add 2 c.c. Nessler reagent. No mixer or stirrer is ever employed in " Nesslerizing " as the high gravity of the Nessler reagent causes it to quickly sink into and mix with the comparatively light distillate. After waiting five minutes, should a brown tint be observed upon looking through the liquid (*longitudinally*) at a white porcelain tile or piece of white paper, the presence of ammonia is indicated.

Continue the distillation and the Nesslerizing of the successive 50-c.c. portions of the distillate until no coloration is obtained after standing for five minutes. When ammonia ceases to be detected, the distilled water may be collected for use. The distillation should not be pushed too far, both on account of danger to the retort and of possible production of ammonia from decomposition of the organic material remaining at the bottom.

Alkaline Potassium Permanganate.—Dissolve 200 grammes solid potassic hydroxide KOH and 8 grammes crystallized potassium permanganate $KMnO_4$ in 1250 c.c. of pure water. Boil down in a porcelain dish to one litre and keep for use.

Standard Ammonium-chloride Solution.—Dissolve 3.8143 grammes of pure dry ammonium chloride in one litre of ammonia-free water. Dilute 10 c.c. of this solution to one litre with ammonia-free water. This second solution will represent a strength of 0.01 mg. of N per cubic centimetre, and is the standard solution used.

NITROGEN AS FREE AMMONIA

Fit a one-quart glass tubulated retort to a large Liebig condenser,* letting the neck of the retort pass well into the condensing-tube. This connection must be thoroughly tight. Place 250 c.c. ammonia-free water in the retort and add about ½-gramme sodium carbonate. Distil off three 50-c.c. tubes of water, and Nesslerize the third in order to be sure that no ammonia yet remains in the retort. Any ammonia that may have resulted from the imperfect cleaning of the apparatus, or that may have been present in the sodium-carbonate solution, will usually all go over in the first 50 c.c. of distillate, but the same quantity (i.e., 150 c.c.) must be distilled off in all cases in order that when the actual analysis of the water is started the condition as to volume may be constant.

* For a description of the retorts, condensers, etc., used by the author see pages 69, 70, and 71.
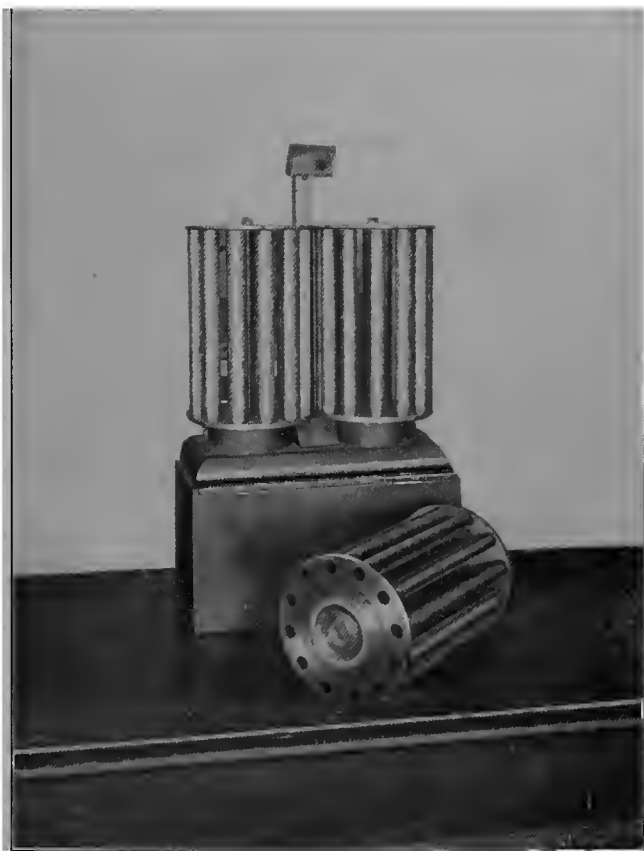
DEVICE FOR READING NESSLER TUBES.

63

In fact, it may be conveniently stated here that *perfect uniformity of conditions* ·is a requisite for success in water-analysis.

To the contents of the retort is now added half a litre of the water to be examined.

Distil and catch the distillate in 50-c.c. Nessler tubes. The rate of the distillation should be so managed as to allow about ten minutes for the filling of each 50-c.c. tube. Add 2 c.c. Nessler reagent to each tubeful. Four tubes will be sufficient to carry off all free ammonia.

From a small burette measure definite amounts of the *standard ammonium-chloride solution* into several clean Nessler tubes. Dilute each to the 50-c.c. mark with ammonia-free water, add 2 c.c. Nessler reagent, and after standing for ten minutes compare as to depth of tint with the distillates already Nesslerized. With a little practice it will be found easy, by varying the amounts of standard ammonia solution used, to produce tints corresponding to those existing in the distillates, and thereby an accurate knowledge of the quantity of ammonia actually present may be obtained. Such ammonia existed ready formed in the water, either free or as an ammonium salt, and passed over unchanged with the steam; it is therefore technically known as "*free ammonia.*"

The author makes use of the following device for reading Nesslerized ammonia-tubes.* The illustration shown on page 63 requires but little explanation. Two disks of brass $\frac{1}{4}$ inch thick and $6\frac{5}{8}$ inches in diameter are joined together by twelve tubes of brass $\frac{13}{16}$ inch in inside diameter and $9\frac{3}{4}$ inches in length. The glass Nessler tubes, which are $\frac{3}{4}$ inch in diameter and 8 inches to the 50-c.c. mark, just fit these brass tubes and are kept from falling through the open bottoms by the holes in the lower brass disk being slightly smaller than the diameter of the brass tubes.

Each lower brass disk is furnished with a very short but broad pivot (3 by $\frac{1}{4}$ inch), which fits into a socket on the wooden stand, thereby permitting the set of tubes to be rotated about a vertical axis. The wooden stand in question has a base of $6\frac{3}{4}$ by $13\frac{1}{2}$ inches, supporting the pair of wooden sockets. Between the sockets is a small mirror set at an angle of 45°, which throws light up through the two Nessler tubes under comparison, and permits the observer to see them in the upper mirror as though in horizontal position. The Nessler standards being placed in the set of tubes on the left and the " free and albuminoid " ammonias in the set on the right, the two sets can be rotated at will

* Supplied by Emil Greiner & Co., New York.

until the colors on the right hand are matched by those of the standards on the left.

To make clear the calculation of results let us cite an example: Suppose the first tubeful to have required 9 c.c. standard ammonia solution (diluted to 50 c.c.) to match its color when Nesslerized, the second one 3 c.c., and the third 1 c.c. Then, since each cubic centimetre of the standard ammonia solution corresponds to 0.01 mg. N, the whole amount of " Nitrogen as free ammonia " present in the original half-litre of water would be:

$$1°. \dotfill 0.09$$
$$2°. \dotfill 0.03$$
$$3°. \dotfill 0.01$$
$$4°. \dotfill 0.00$$
$$\overline{}$$
$$0.13 \text{ mg.}$$

Multiplying this by two to obtain the quantity for an entire litre, and remembering that 1 mg. is the millionth part by weight of a litre of water, we find the total " Nitrogen as free ammonia " present in the water to be 0.26 *part per million.*

Permanent Standards.—In laboratories where much work is done in water-analysis it is very convenient to keep at hand sets of standards for quickly reading the Nesslerized ammonia-tubes and also the colors

obtained in the iron and other determinations. Such standards are prepared by diluting suitable mixtures of sundry colored solutions. Useful as they are to men of experience, it is questionable if it be wise to put them into the hands of students who may by their use lose sight of what the real standards are. The writer objects to their employment in a laboratory of instruction for practically the same reason that he opposes the too liberal use of factors in general quantitative analysis.

NITROGEN AS ALBUMINOID AMMONIA

Throw out the residue remaining after the distillation for *free ammonia*, clean the retort thoroughly, and refit it to the condenser. Place in the retort 200 c.c. ammonia-free water and 50 c.c. of the *alkaline permanganate solution*. Distil off three 50-c.c. tubes, and Nesslerize the third one in order to insure freedom from ammonia. Add half a litre of the water under examination, and proceed with the distillation, and the Nesslerizing of the successive 50-c.c. portions of the distillate, as in the determination of *free ammonia*. The distillation is to be continued until five 50-c.c. tubes are filled. The ammonia determined by this distillation will be *total* (i.e., " free " plus " albuminoid "); therefore from the Nessler reading of each tubeful of distillate

must be subtracted the reading for the corresponding tubeful for " Nitrogen as free ammonia ": the difference will give the " Nitrogen as albuminoid ammonia " for that tube.

The calculation is entirely similar to that for *Nitrogen as free ammonia,* as stated.

It must be understood that the retorts and condensers hitherto described are such as would be found in a general laboratory and are not the best and most convenient for special water work. The " ammonia table " used by the author is pictured on page 71. The supports are all of piping. Those holding the retorts also carry gas for the lamps and those for the condensers convey the cooling water. Along the middle of the table are openings leading to the sewer to which the condenser water escapes. Connection between retort and condenser is made by a mercury seal.*

In working the " albuminoid-ammonia " process it is of importance that sundry minor details should be observed in order that concordant results may be obtained.

The Nessler tubes used are long and narrow,

* All the glassware here described can be supplied by Emil Greiner & Co., New York.

being 11½ inches total length, and 8 inches from the bottom to the 50-c.c. mark. They should always be rinsed with ammonia-free water immediately before using. A very convenient lamp for heating the retorts is the broad flat Bunsen (3½ inches diameter) with numerous small jets over its surface.

———

Keep the current of cooling water passing through the condenser at a velocity such that the difference between the temperature of the inflowing and outflowing water shall not exceed one degree centigrade.

———

Be very careful to have the " standard ammonia " solutions and the distillates at the same temperature when the Nessler reagent is added; otherwise equal strengths of ammonia would strike different shades of color and produce error. This end is best achieved by allowing the distillates to attain the temperature of the room before adding the Nessler reagent. Daylight is best for reading Nessler colors, but if necessary a Welsbach burner may be used.

———

Even with the utmost precaution some ammonia will be lost through imperfect condensation, and this loss will be greater in proportion as the rate of distillation is made more rapid.
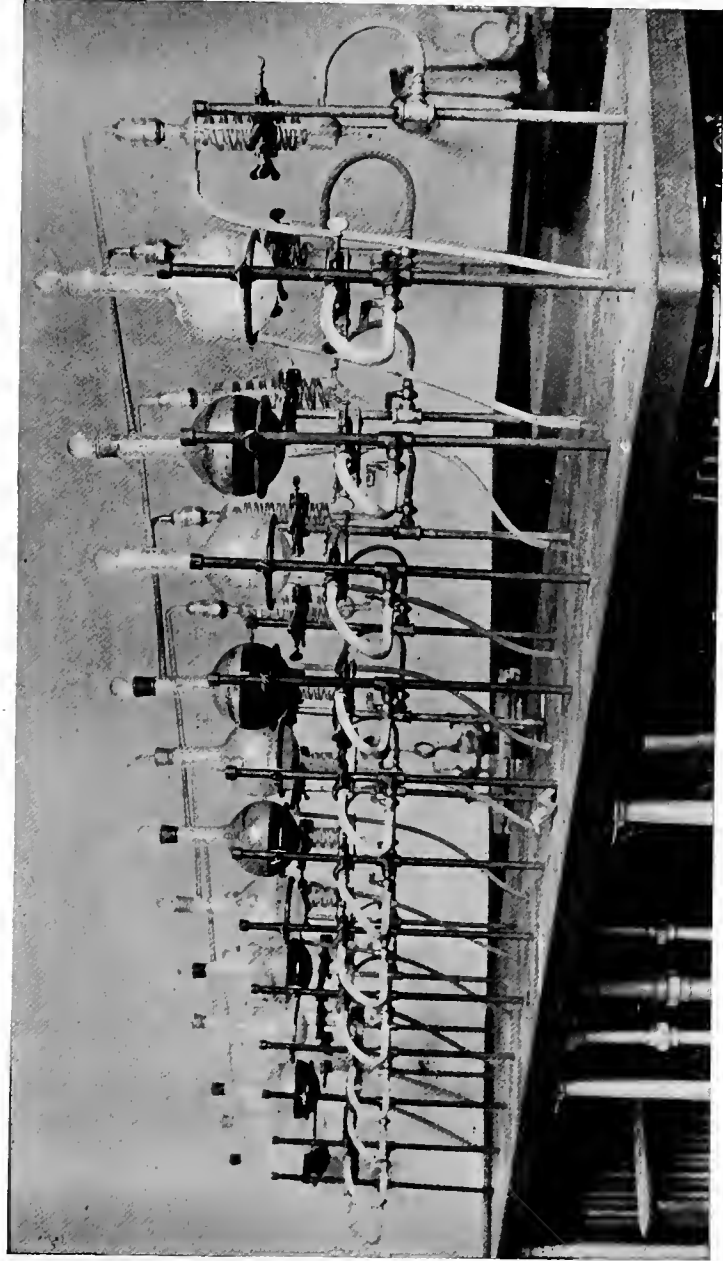
SHOWING RETORTS, CONDENSERS, AND NESSLER JARS FOR "ALBUMINOID-AMMONIA" PROCESS.

The amount of ammonia in the distillate being a function of the time employed, it becomes necessary to eliminate, so far as may be, any error that might arise from this source by conducting all distillations as nearly as possible at the same rate. So manage the lamp, therefore, as to fix the time required for the distillation of each 50 c.c. at *ten minutes*.

———

It is not sufficient to note the *total* amount of " free " and " albuminoid " ammonias, but the full notes of the Nesslerizing process must be retained, that the *rate* at which the ammonia passes over may be observed. (See page 83.)

———

Do not observe the tint of a Nesslerized solution until ten minutes after the addition of the reagent. After the expiration of that time the color may be considered constant, no further material change taking place in twelve hours. Consequently, in the case of the examination of many successive samples, the Nesslerized standard solutions need not be made up for each water, but those prepared in the morning may be used during the entire day, proper care being taken to protect them from the action of the atmosphere by covering them when not in use.

The routine standards are: 0.00, 0.0025, 0.005, 0.0075, 0.01, 0.015, 0.02, 0.03, 0.04, 0.05, 0.06, and 0.07.

Higher colors than these cannot be read with accuracy. Should the ammonias run beyond the highest of the above standards, remove a definite amount from the Nessler tube, dilute it to the 50-c.c. mark, compare with the routine standards, and allow for such dilution.

Much trouble was formerly experienced from the low standards becoming clouded or "smoky." This was found to have been due to the fact that, in making the distilled water, the water in the copper retort had been allowed to run too low, resulting in volatile decomposition products being evolved from the concentrated organic matter.

Occasionally a citron-green color is produced which masks the ammonia reaction and renders its estimation difficult. Dr. Kidder, of the navy, observed this interference with the ammonia coloration, and attributed it to the presence of substances evolved in the putrefaction of organic matter. He concluded from the few experiments he made that the amines are not necessarily concerned in its production, as he found that butyric acid gave a somewhat similar interference to that met with.[*]

[*] Reference Handbook of the Medical Sciences, p. 157.

As has already been pointed out, water-samples will not keep long; whence the necessity for a speedy analysis after the collection is once made.*

With many waters the tendency is for " free ammonia " to disappear upon keeping; and, as a rule, the " albuminoid ammonia " also diminishes, but this rule is by no means uniform. For instance, the writer found that a certain brown water, after ten days' storage, showed an increase in " free ammonia " from 0.125 to 0.28 and a decrease in " albuminoid ammonia " from 0.255 to 0.235. The following equation,† giving the decomposition of albumen, illustrates the breaking up of albuminoid materials and the increase of " free ammonia."

$$C_7H_{14}N_2O_3 + 6H_2O = (NH_4)_2CO_3 + 3CH_4 + 3CO_2 + 3H_2.$$
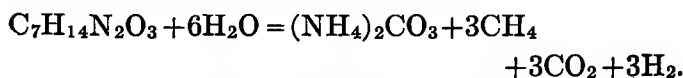
It indicates one of the steps in the " cycle of organic nitrogen."

From observations made upon the appearance and disappearance of nitrites there seems to be little doubt that the loss of " free ammonia " is to be accounted for by a process of nitrification. Nitrites are formed at the expense of the ammonia, and they,

* The changes which take place in water upon keeping have been carefully investigated by Smart and Mallet (Nat. Board of Health, 1882).

† Barwise, " Purification of Sewage," p. 33.

in their turn, are converted into nitrates, by further oxidation. Nitrogenous organic matter in water may be considered as belonging to two classes: *first*, "that which passes readily into the condition of 'free ammonia' through putrefactive agencies," and which is consequently easily acted upon by the alkaline permanganate solution; and, *second*, that which is more stable, and from which no ammonia is evolved during distillation with the above reagent. Upon standing for any considerable time this latter class becomes slowly converted into the less stable variety, which in its turn is gradually converted, at least in part, into "free ammonia," the ammonia in turn becoming finally nitrified, as already stated. Thus we have a perfect system of changes, from the stable nitrogenous organic matter on the one hand to the fully oxidized nitrate on the other. Of course we are citing but a typical case, and must be prepared to see all manner of departures therefrom in special instances, according as the character and amount of materials and the nature of the environment may differ.

If the albuminoid ammonia be redetermined after the sample has stood a number of days an idea might be obtained of the stability of the nitrogenous organic material whence such ammonia was derived.

Should hydrogen sulphide be present in the water it would pass into the distillate and react with the Nessler reagent. In such a case place the half litre of water in the retort. Add 50 c.c. normal H_2SO_4. Distil off 100 c.c. of water. Add 50 c.c. of normal NaOH sodium carbonate and proceed as usual.*

————

Interpretation of Results.—Concerning the interpretation of results, Wanklyn, the originator of the method, is very dogmatic, and says: " The analytical characters, as brought out by the ammonia process, are very distinctive of good and bad waters, and are quite unmistakable. There is, indeed, hardly any branch of chemical analysis in which the operator is less exposed to the risk of failure."

This statement is altogether too strong. Waters of high organic purity or those of gross pollution are relatively easy to classify, but with the numerous cases which lie about the boundary-line between " good " and " bad " the greatest care is to be exercised in the reading of results and the passing of judgment. One rule, already mentioned, and upon which too much stress cannot be laid, is never to give an opinion concerning a water the history and surroundings of which are not thoroughly known.

* Bartow and Harrison. *Science*, xxxii, 477.

As an illustration of variation in the ammonias, the following data are offered (see also page 86):

	Free Ammonia.	Albuminoid Ammonia.
Average in sundry surface-waters known to be pure	0.063	0.066
Average in sundry surface-waters known to be polluted	0.182	0.228
Average in sundry ground-waters known to be pure	0.009	0.007
Average in sundry ground-waters known to be polluted	0.107	0.081

The " free ammonia " in artesian wells is often excessive under circumstances that make animal contamination an impossibility, and even rain-water, freshly collected after periods of long drought, will often exhibit properties calculated to mislead the analyst.

C. B. Fox gives the following determinations in pure *deep-well* waters:

	Free Ammonia.	Albuminoid Ammonia.
Well 230 feet deep	0.80	0.05
" 250 "	0.76	0.04
" 300 "	0.74	0.03
" 330 "	0.37	0.06
" 385 "	0.59	0.04
" " very deep "	0.41	0.07

This excess of free ammonia may be due either—

" 1. To entrance of rain-water;

" 2. To the beneficial transformation of harmful organic matter into the harmless ammonia, through

the agency of sand, clay, and other substances which act on the water in a manner similar to the action of a good filter;

" 3. To some salt of ammonia existing in the strata through which the water rises; or,

" 4. To the decomposition of nitrates in the pipes of the well. Mr. H. Slater suggests that the agent concerned in this reduction may, in the case of the deep-well waters, be the sulphide of iron which is found in the clay.

" We conclude, then, that the presence of free ammonia in such comparatively large quantities in these deep-well waters is due to the reduction of nitrates and nitrites by sulphide of iron, or some kinds of organic matter, or some other agent, such oxidized nitrogen salts having been produced in past ages by the oxidation of organic matter." *

Free ammonia in deep-well water may, however, be derived from very objectionable sources; as when surface pollution is admitted because of cleavage and fracture cracks in friable rocks, and because of the " dip " of the strata being nearly vertical. The writer has seen numbers of such cases.

Take, for instance, the water from a rock-drilled well in friable shale. The boring was 57 feet deep and was located in a city containing many privy-

* Fox, " Sanitary Examinations of Water, Air, and Food."

vaults, the nearest of which was 75 feet distant. The " free ammonia " reached the very high figure of 2.025, and curiously enough there was no " albuminoid ammonia " whatever. An additional item condemning this water was the large amount (69 parts per million) of chlorine present.

Free ammonia is at times very high in the rain-water collected near large cities, and is liable to run higher in winter than in summer. Of course high figures under such conditions are without objection, assuming a clean roof and a clean cistern; but when dealing with rain-water it must be always borne in mind that storage cisterns are often very foul.

Dr. Drown points out the low values commonly found for both " ammonias " in ground-waters of good quality, and places that for albuminoid ammonia as rarely exceeding 0.025. He shows the influence of growing plants in reducing free ammonia in surface waters, and quotes as illustration the great difference in this item in the water of Mystic Lake with change of season; thus two readings for free ammonia were:

$$
\begin{array}{ll}
\text{August} & 0.000 \\
\text{January} & 0.573
\end{array}
$$

A further point that is mentioned by the same observer is the liability to high free-ammonia

readings in water from wells sunk in ferruginous, swampy regions, because organic matter associated with oxide of iron furnishes in absence of oxygen favorable conditions for development of ammonia.*

Water passed through newly laid and rusty mains will often become materially changed in chemical character as well as in physical appearance. The influence of the iron-rust is to reduce the nitrates present and increase the nitrites and free ammonia. A good water might thus be very readily condemned upon the analytical results alone did the analyst not know its antecedents.

Wanklyn would clear away all difficulty of interpretation by holding that " albuminoid ammonia above 0.10 part per million begins to be a very suspicious sign; and over 0.15 it ought to condemn a water absolutely." Such a hard-and-fast rule is too severe for general application.

Many an excellent water is seen to greatly exceed these limits, particularly the brown waters supplying some of our Eastern towns. Numerous peaty waters, of proved wholesomeness, far exceed them. As has already been pointed out, waters of a brown or peaty character are always to be looked upon very narrowly, but many of them are unquestionably

* Mass. Board of Health, 1892, 324.

of good quality, and all of them would be condemned by the proposed standards.

The analyst must here again use his good judgment and decide whether or not there is natural and harmless cause for the high ammonia readings.   The depth of color of the water will be a material guide to his decision.

The analysis of the water from a mountain lake situated far away from all possibility of sewage contamination, gave the following results:

> Free ammonia................ 0.01
> Albuminoid ammonia.......... 0.34

An excellent mountain stream recommended for a city supply, although but slightly colored, ran:

> Free ammonia...... .. .. 0.055
> Albuminoid ammonia........ 0.230

As a result of the analysis of fifteen drinking-waters from widely scattered sources, many of them city supplies, and all of them believed to be wholesome, Prof. Mallet gives figures for " albuminoid ammonia " that show an average of 0.152 part per million (highest $= 0.325$, lowest $= 0.020$).   Most of these would be condemned by the Wanklyn standard.

Some years ago Dr. Smart pointed out that the

rate at which the ammonia is evolved is of an importance at least equal to, if not greater than, the total amount of the same; he holds that: " *Gradual* evolution of albuminoid ammonia indicates the presence of organic matter, whether of vegetable or animal origin, in a fresh or comparatively fresh condition, while *rapid* evolution indicates that the organic matter is in a putrescent or decomposing condition."

This is entirely in accord with present experience. Thus the evolution of albuminoid ammonia was found as follows when analyzing the water of a mountain lake in which was a considerable growth of pond-lilies and other water-plants:

Nessler tube No. 1	0.0600
" " 2	0.0450
" " 3	0.0250
" " 4	0.0150
" " 5	0.0100
" " 6	0.0075
" " 7	0.0050
" " 8	0.0025

$$0.1700 \times 2 = 0.34$$

Water giving such results can be looked upon with much more favor than one presenting an albuminoid record such as the following:

Nessler tube No. 1........	0.1000
" " 2........	0.0350
" " 3........	0.0125
" " 4........	0.0025
" " 5........	0.0000
	$0.1500 \times 2 = 0.30$

Thus we see that the interpretation of results is entirely a question of opinion and sound judgment, and in this connection Mallet's conclusion cannot be read without marked interest; he says: " It is impossible to decide absolutely upon the wholesomeness or unwholesomeness of a drinking-water by the mere use of any of the processes for the estimation of organic matter or its constituents. I would even go further, and say that, in judging the sanitary character of a water, not only must such processes be used in connection with the investigation of other evidence of a more general sort as to the source and history of the water, but should even be deemed of secondary importance in weighing the reasons for accepting or rejecting a water not manifestly unfit for drinking on other grounds. There are no sound grounds on which to establish such general standards of purity as have been proposed."

As a further aid to judgment analyses of sundry

waters in different parts of the country are given on the next page, several of them having caused disease. Also a few instances of waters of reliable quality including certain city supplies. As elsewhere throughout the book, the results are in parts per million.

It will be observed that several of the impure waters quoted have figures for free ammonia higher than those for albuminoid ammonia. This is always a suspicious sign, unless both numbers in question be low.

One of the worst waters in the list, number two, would not have been condemned upon the ammonia items at all, thus showing the importance of judging from the completed analysis. Water number three was from a well drilled in friable shale and within short distance of city privies. Water number four was from an isolated country summer residence. The water is materially higher in " chlorine " and " nitrates " than the local " normals," and is exposed to drainage from outhouse and stables.

Water number nine was from a well drilled into Hudson River shale, and protected from immediate surface drainage. The chlorine rose from 58 to 64.3 some fifteen hours after emptying a bushel of salt into a privy-vault fifty feet distant.

Water number ten was from a drilled well, in

Number.		Free Ammonia.	Albuminoid Ammonia.	Chlorine.	N as Nitrate.	N as Nitrite.	Required Oxygen.	Total Solids.
1	Shallow city well...............	0.026	0.08	122	17.38	trace	1.4	554
2	City well 30 ft. deep (caused typhoid).................	0.005	0.035	146	10	0	1	769
3	Rock-drilled city well 57 ft. deep..	2.025	0	69	0.025	0	0.85	487
4	Spring-water (caused repeated cases of dysentery)...	0.01	0.025	6	7	0	0.8	36
5	Well near city.................	0.005	0.045	24	9	0	1.1	216
6	City well......................	0.4	0.04	93	1.5	.005	....	380
7	Town well.....................	0.815	0.075	36	0	trace	....	421
8	City well 250 ft. deep..........	1.59	0.395	102	0	trace	....	681
9	City well 255 ft. deep..........	0.31	0.02	58	0	0	6.45	635
10	City well 226 ft. deep..........	1.11	0.08	199	0	0	1.3	779
11	Deep well in large stockyard, Kansas City...............	1.725	0.025	50	0	trace	....	.....
12	Hudson River, at Troy, during freshet.................	0.42	1	3	0.5	trace	....	205
13	Deep city well, in " made ground "	excessive	excessive	47	0.875	0	2.5	637
14	Hudson River, near Albany, N. Y.	0.078	0.346	1.87	0.44	.008	14.4	125
15	Mohawk River, near Cohoes, N. Y.	0.104	0.176	2.25	0.6	.002	6.8	137
16	Niagara River, Niagara Falls......	0.036	0.122	7.25	0.12	.001	2.9	152
17	Town supply, Elizabethtown. N. Y. (brook)......................	0.048	0.002	1.05	0.05	0	0.35	106
18	Lake Placid, N. Y..............	0.022	0.052	0.75	0.50	.001	1.3	192
19	Syracuse, N. Y., (lake water).....	0.012	0.020	1.5	0.36	.003	1.8	122
20	Wachusett Res, Boston..........	0.022	0.143	2.8	0.03	0	4.0	34.8
21	Pittsfield Res.................	0.026	0.161	1.0	0.01	0	4.0	32.7
22	Kensico Res., New York City.....	0.005	0.055	1.5	0.10	.002	....	58
23	Peaty mtn. stream (autumn).....	0.056	0.23	2.4	0	0	7.4	34
24	Same stream in winter...........	0.055	0.117	1.9	0.08	0	6.6	47
25	High mountain lake (peaty)......	0.01	0.34	2	0	0	6.6	43
26	Lake Erie (middle of lake)........	0.045	0.112	3.5	0.08	trace	1.25	134
27	Lake Superior (40 miles from shore)......................	0.03	0.02	1	0.1	0	1.15	54
28	Large well-situated spring........	0.027	0.006	2.2	1.6	0	0	90
29	Mountain spring................	0.04	0.048	4	1.404	trace	0.3	228
30	Domestic well (Catskill Mountains)......................	0.016	0.007	0.75	0.175	0	0.35	32
31	Flowing wells (N. J. coast).......	0.023	0.05	9	0.5	trace	0.4	30
32	Driven wells (Hempstead, N. Y) ..	0.013	0.004	2.5	1.25	0	0.35	22
33	Schenectady, N. Y. (ground water)	0.016	0.016	4.5	0.50	.001	1.3	192
34	Lowell, Mass., (ground water)	0.300	0.058	3.6	0.22	.001	....	59.8
35	Brookline, Mass., (ground water)..	0.062	0.070	7.5	0.19	.001	....	86.9
36	Middleboro, Mass., (ground water) .	0.055	0.062	6.8	0.43	0	....	65.8
37	North Woods Club, Remote forest spring........................	0	0.020	2.0	0.28	trace	0.25	83

(Rows 1–16: Poor quality. Rows 17–37: Good quality.)

shale rock, constructed with much more care than usual. Extreme precautions were taken to shut out all immediate surface drainage, and they were un-

doubtedly successful. Nevertheless the neighboring privies contributed their seepage, raising the " free ammonia " and " chlorine " tremendously above the local " normals." Such results show us how unsafe it is to trust to the purity of rock-drawn water, when, owing to the seamy character of the rock, and the direction and angle of its " dip," almost direct connection may be established between the bottom of the well and the surrounding sources of surface pollution.

The bore-hole in some rocks, if not in all, is not truly circular in section and opportunity is presented for pollution to flow down in the space between the well-casing and the rock wall, thus reaching the bottom of the well.

A comparison of waters twenty-three and twenty-four shows the influence of freezing weather in tying up the fountains of " peaty " contamination.

OXYGEN-CONSUMING CAPACITY. (" REQUIRED OXYGEN.")

This determination (which must not be confused with that of " dissolved oxygen ") deals principally with the carbon present in the organic matter and is Kubel's modification of the old permanganate process of Forschammer. The original mode of pro-

cedure was published in 1850, and "consisted merely in adding a solution of potassic permanganate of known strength, without any other reagent, to a measured amount of water to be examined, until the liquid had acquired a faint permanent tinge, and then noting the quantity used. It was afterwards ascertained that more uniform results could be obtained, and with less expenditure of time, by causing the permanganate to act in the presence of free acid or free alkali." Kubel uses a boiling temperature. The reagents required are:

Standard Potassium Permanganate Solution.—Dissolve 0.3952 gramme of the salt in one litre of distilled water. Each cubic centimetre of such solution will contain 0.1 mg. of oxygen available for oxidation. The available oxygen of the permanganate in presence of sulphuric acid may be represented by the equation

$$2KMnO_4 + 3H_2SO_4$$
$$= K_2SO_4 + 2MnSO_4 + 3H_2O + 5O.$$
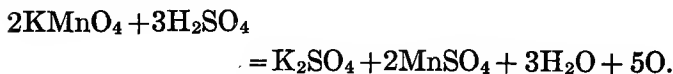
Dilute Sulphuric Acid.—One part of the strong acid to three of distilled water.

Solution of Oxalic Acid $(H_2C_2O_4 \cdot 2H_2O)$. — Dissolve 0.7875 gramme of the crystallized acid in one litre of distilled water. This solution if titrated against the permanganate solution (while hot and

in presence of H_2SO_4) should correspond to it c.c. for c.c. In practice, however, this correspondence will be found to be approximate only. The equation is

$$2KMnO_4 + 3H_2SO_4 + 5(C_2H_2O_4 \cdot 2H_2O)$$
$$= K_2SO_4 + 2MnSO_4 + 10CO_2 + 18H_2O.$$
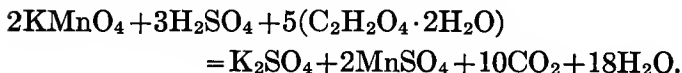
The solution tends to grow weaker quite rapidly with lapse of time, and must be restandardized every time it is used. This is, however, but a slight inconvenience, and is accomplished as follows:

Ten c.c. of the oxalic-acid solution, diluted with 200 c.c. distilled water and 10 c.c. of the dilute sulphuric acid, are titrated, boiling, with the standard potassium permanganate solution, and the amount of the latter required to produce a faint pink tinge is recorded.

Determination.—Place in a porcelain casserole 200 c.c. of the water under examination, and add 10 c.c. of the dilute sulphuric acid. Heat rapidly to incipient boiling, and run in the standard permanganate solution from a burette until the water has a marked red color. Boil *thirty minutes*, adding more permanganate from the burette from time to time, if necessary, in order to maintain approximately the intensity of red color observed at the start. Do not let the color fade nearly out, and then add

the permanganate in quantity, but strive to keep
the color as nearly constant as possible by gradual
addition.   Add a little distilled water from time to
time to replace the loss due to evaporation.

Remove the lamp, add 10 c.c. (or more, if neces-
sary) of the oxalic-acid solution to destroy the color,
and then add the permanganate solution, from the
burette until a faint pink tinge again appears.   From
the total permanganate used deduct that corre-
sponding to the 10 c.c. (or more) oxalic acid em-
ployed, and from the remainder calculate the milli-
grammes of " required oxygen " consumed by the
organic matter present in the water.   Correction
must be made for nitrites, ferrous salts, or hydrogen
sulphide if any of them be present.

Example:

	c.c.
Total permanganate solution used............	25
Less that required for the oxalic acid.........	9.7
Hence that required to oxidize organic matter..	15.3

corresponding to 1.53 mg. oxygen.

Therefore " required oxygen " is $1.53 \times 5 = 7.65$ per
million.

Comparates.—As this determination deals princi-
pally with the organic carbon present, the readings
are naturally high in the cases of brown peaty

waters, and surface-waters carrying organic matter in suspension. (See the list of analyses, page 86.)

Average in sundry surface-waters known to be pure........ 1.58
   "   "   "   "   polluted...... 3.00
   "   " ground-waters   "   pure........ 0.31
   "   "   "   "   polluted...... 1.06

Averages from determinations by Dr. Smart:

> Impure (14 samples).......... 5.880
> Doubtful purity (5 samples)... 3.073
> Medium purity (15 samples)... 1.414
> Pure (18 samples)............ 0.581

The severe character of the following French classification is due to the fact that spring-waters are popular in France, and surface-waters are filtered before use:

> Very pure................... 1
> Potable..................... 2
> Suspected.. .... 3 to 4
> Impure.... .... above 4

In the opinion of the writer the determination of " required oxygen " does not furnish information of great value. Deeply colored waters, otherwise pure, are sure to give high results, because of the quantity of carbon present, and a simple inspection, with

measurement of the color, would give equally valuable information.   •

For the accurate determination of either lead or copper considerable quantities of the water should be evaporated and the residue then examined by the scheme to be found in works on general quantitative analysis. For the approximate estimation, which is often sufficient, the ease with which their dark sulphides may be formed provides a ready method (Miller).

Prepare a *standard solution of lead nitrate,* $Pb(NO_3)_2$, by dissolving 1.599 grammes of the salt in one litre of distilled water. Each cubic centimetre will contain 1 mg. metallic lead.

Precipitate metallic copper electrolytically in a platinum dish, weigh, dissolve it in a few drops of HNO_3 and dilute with sufficient water to allow each c.c. of the solution to contain 1 mg. metallic copper. Use this as the *standard copper solution.*

Place the water in a 100-c.c. Nessler tube, slightly acidify with HNO_3, pass H_2S, and match the tint by operating in a similar manner with measured amounts of the standard lead or copper solution diluted to 100 c.c.

This method will not, of course, distinguish be-

tween copper and lead, but distinguishing is not commonly necessary.

High natural color in the water interferes with the determination.

For the detection of copper in water which has been treated with copper sulphate for algæ removal, a convenient test is the following:

Concentrate if necessary.

Add a few drops of formaldoxime* (prepared by dissolving 1 part of hydroxylamine hydrochloride in 5 parts of formaldehyde).

Add some strong KOH solution.

A violet color indicates copper.

The color fades quickly and must be matched at once for quantitative purposes.

IRON

This metal is objectionable if present in considerable quantity, particularly in water to be used for washing white goods, and for dyeing. A knowledge of the presence of iron will, moreover, aid in guarding against an invasion of crenothrix.

The *standard iron solution* is prepared by dissolving 0.1 gramme pure iron in a little HCl to which a few drops of HNO_3 have been added, evaporating to dryness, moistening with HCl, and then

* Trans. Chem. Soc., 1898.

diluting to one litre. One c.c. of this solution will contain .1 milligramme of iron.

Determination.—Take 100 c.c. of the water; evaporate to dryness; ignite at low redness sufficiently to decompose organic matter; add 5 c.c. concentrated HCl; warm, dilute slightly, filter if necessary and wash; dilute to 100 c.c. in a Nessler tube, add a few drops of $KMnO_4$ solution (5 grammes per litre) to make the slight pink color persist five minutes; add 5 c.c. KCNS solution (20 grammes per litre), and compare the depth of color produced with those formed by known amounts of standard iron solution which have been diluted and treated in the same way with similar quantities of HCl, $KMnO_4$ and KCNS.

The standards must be made at the same time because time is an element in this determination. The red color produced tends to pale out even after a few minutes' standing. Comparison must be made at once.

———

Iron which tends to increase in a well-water as the draught upon the underground supply grows in volume is a discouraging symptom; for the probabilities are strong that the water will eventually become unfit for use unless the ever-increasing iron be artificially removed.

At Lowell, Mass., the changes in the iron content of the driven well-water were:

1896–00	0.322 p.p.m. Fe
1901–05	0.341 "
1906–10	0.770 "
1911–13	1.468 "

Finally an iron removal plant had to be established.*

In his " Filtration of Public Water Supplies," page 186, Hazen says:

" Three-tenths of a part per million of metallic iron very rarely precipitates or causes any trouble.

" In iron removal plants an effluent containing less than 0.5 is regarded as satisfactory. One containing less than 0.2, as in the case with many plants, is all that can be desired."

As the result of wide inquiry among those interested in water for laundry purposes, the writer concludes that iron to the extent of 0.25 part per million may be considered satisfactory: more than 0.5 part per million unsatisfactory; and the values between doubtful.

In this connection note the conflicting statements made by the following Massachusetts communities;

* See Barbour's report to the Municipal Council, 1914.

the figures given indicate the amounts of iron in the several waters:

Methuen......... 0.365 satisfactory
Grafton...... . 0.507   "
Newburyport..... 0.720   "
Cohasset........ 0.380 not satisfactory
Hyde Park....... 0.859   "

It is well to note in this connection that it takes about 0.3 part per million of iron in solution (not colloidal nor suspended) to sustain a growth of crenothrix.

ZINC

Zinc is not a cumulative poison, but its presence in a water is nevertheless undesirable. Galvanized-iron pipe is attacked by certain waters, especially those that are soft, and spring-water is at times zinc-bearing, as has been especially noticed in Southern Missouri.*

* Zinc-bearing spring-water from Missouri:

	Parts per Million.		Parts per Million.
$PbSO_4$.................	trace	$CaSO_4$................	109.9
$CuSO_4$..................	0.5	$MgSO_4$...............	19.0
$CdSO_4$..................	0.9	K_2SO_4...............	5.6
$ZnSO_4$..................	297.7	Na_2SO_4..............	5.9
$FeSO_4$..................	1.6	$NaCl$................	4.3
$MnSO_4$.................	6.3	$CaCO_3$...............	72.0
$Al_2(SO_4)_3$...............	2.5	SiO_2.................	13.7

                539.9

(Hillebrand, Bul. 113, U. S. Geol. Sur.)

For the determination of the metal in absence of lead, copper, and manganese evaporate three litres of the water to dryness in presence of HCl.

Bake for an hour at 110° C. Moisten with HCl, add water and filter off SiO_2. Make alkaline with NH_4OH, boil and filter off the hydroxides of iron and aluminum. Dissolve the precipitate in a little HCl and reprecipitate it with NH_4OH. Filter and reject the precipitate. Unite the two filtrates. Boil off the ammonia. Make acid with acetic acid, and while still hot pass H_2S. Let the precipitate settle. Filter and dry. Remove the precipitate from the paper. Ignite the paper in a porcelain Rose crucible. Add the precipitate and ignite for fifteen minutes in a stream of H_2S. Weigh as ZnS.

For qualitative purposes, Allen's test is useful: Acidify the clear water with HCl; make slightly alkaline with ammonium hydroxide; boil; filter, and add a few drops of potassium ferrocyanide. A white precipitate will form in presence of a trace of zinc.

When applying this test it must be remembered that only the zinc in solution is detected. That portion which is present in insoluble form, suspended in the water, is often the larger of the two.

———

Reports recording that a water contains so many parts per million of lead, zinc, or other metal are

common enough, but it is rare to find advance statements of what a water is capable of doing in the way of dissolving metals should opportunity be afforded it of coming in contact with them. In other words, a client who possesses a water supply which is very desirable at its source is seldom informed of the possible damage which may result thereto by reason of its being conveyed through metallic piping.

After the pipes have been laid and the water admitted to them, record is made of the result as to the metallic solvency, but little is found in the nature of a prophecy antedating the outlay of capital; which prophecy, had it been uttered in time, might have had material bearing upon the investment. Again, if, as occurs in a few instances, the client be told that the water under examination is capable of acting upon certain metals, he is seldom given the information in such quantitative form as will enable him to make comparisons between it and other waters with reference to this property.

It is well known that all waters do not equally possess the power to attack metals and it is proper to ask that, granting that such power does exist, how far is its exercise objectionable from a sanitary point of view; or, to state it differently, what amount of metallic salts in solution may be allowed with safety?

There is some difference of opinion among the authorities as to the amount of contained lead required to condemn a water, but all are agreed that even small quantities should be narrowly watched. Thus, the Massachusetts reports note that one-half part per million has caused serious injury.* Haines holds that 0.1 grain per U. S. gallon (1.71 per million) should cause a water to be rejected.†

Whitelegge believes that " No water should be used for drinking which contains more than one part of lead per million, and any trace, however minute, indicates danger." (Hygiene and Public Health.)

Middleton considers 1.4 parts per million of either lead or copper sufficient to condemn a water.‡

To quote Dr. Summerville in his recent paper in *Water:* " Lead to the extent of 0.25 part per million is sufficient to condemn a potable water."

In four cities of Massachusetts where lead poisoning was produced the average amount of the metal present during ordinary daytime use was one part or more per million. Occasional instances of " plumbism " were noticed in other towns and doubtless mild or unrecognized cases occurred elsewhere.§

* Mass. State Board of Health, 1898, XXXII.
† *J. Fk. Inst.*, Nov., 1890.
‡ " Water-supply," page 21.
§ Mass. State Board of Health 1898, p. 543

In the thirty-first annual report of the London Local Government Board (1901 and 1902 Supplement on Lead Poisoning and Water Supply, Vol. 2, p. 426), peaty moorland waters are shown to be especially plumbo-solvent, to a degree chiefly governed by the amount of acidity present, and experiments show that such acidity is due, at least in part, to acid-forming bacteria residing in the peat.*

The London report is so firm in its belief that the cause of plumbo-solvency had been located that it ventures to rate the moorland waters as " safe " if they are neutral to lacmoid and as " dangerous " if they react acid with that indicator.

H. W. Clark observed that carbonic acid in a soft water was the main factor that caused lead to be taken into solution by the waters of Massachusetts.†

It is by no means new to distinguish between the " solution " of lead and that " erosion " of the metal which some waters exercise whereby insoluble lead salts are formed with appreciable increase in the turbidity of the water.

For our purposes it will suffice to note that " erosion " does not occur in the absence of oxygen, and we are also to remember that from the sani-

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* See also Thresh, " Examination of Water," p. 186.
† *Engineering News*, Dec. 1, 1904.

tarian's point of view " erosion " may be fully as objectionable as " solution " if no opportunity for clarification be furnished. In fact, the former may readily be the greater evil of the two, because of its involving the possibility of the ingestion of large quantities of lead salts held in suspension.

The writer believes that no water to be used for drinking purposes should contain lead compounds in quantity greater than what would correspond to half a part per million of metallic lead.

Piping water in tubes of galvanized iron is very common, and as zinc is often more easily attacked than lead it is pertinent to ask if it be equally dangerous. So far as our present experience can guide us towards a correct solution of this question, the reply must be a negative one and the following opinions are presented in support of such contention:

In the Journal of the German Society of Gas and Water Engineers for 1887, H. Bante collected statistics to show " that the use of galvanized pipes should be in no way detrimental to health."

Similar views are entertained by V. Ehmann, director of the water supply of Wurtemberg.*

* J. Fk. Inst., 1890.

According to Thresh * " there is no doubt that waters containing traces of zinc are used continuously for long periods without causing any obvious ill effects. The water supply to a small hospital with which I was connected for some years always contained a trace of zinc, probably never more than half a grain of the carbonate per imperial gallon (7.1 parts per million), but I never observed any indications of its being deleterious, although such effects were looked for."

In the Massachusetts Board of Health report for 1900, page 495, the following table is given showing amounts of zinc in sundry public supplies, the metal having been dissolved from pipes of galvanized iron or brass during ordinary use. The results are averages and are in parts per million:

West Berlin	18.46
Milbury	3.08
Newton	1.25
Marblehead	0.85
Grafton	0.73
Wellesley	0.68
Fairhaven	0.52
Lowell	0.33
Webster	0.28

* " Examination of Waters and Water Supplies," p. 85.

Sheffield...................... 8.65
Palmer........................ 2.90
Beverly....................... 2.71
Fall River.................... 0.07

The first of the above, West Berlin, drew its water through 4000 feet of galvanized iron pipes. The quantity of metal dissolved therefrom was certainly large, but appears to have produced no evil results. " As far as is known the amount of zinc present in these waters as used is not sufficient to have any effect upon the health of the consumers of the water.

" The Board has investigated the question of the presence of zinc in drinking-water supplies where galvanized iron pipes are used, and except in case of the use of some ground-waters, containing very large amounts of free carbonic acid, which dissolves zinc and many other metals very freely, the amount of zinc found in ordinary water-supplies, where galvanized pipes are used, is not sufficient, in the opinion of the Board, to give anxiety." *

In a private letter of more recent date the president of the above mentioned board says: " If there had been any harmful effects of the presence of zinc in the public drinking-waters of the state that

* Massachusetts Board of Health, 1902, XLIII.

fact would have undoubtedly been brought to our attention. No statement to this effect had been made, nor has there seemed to this board reason suspecting serious danger from this source."

As an instance of long continued use of a water containing much zinc, the case of Brisbane, Queensland, should be quoted. In that city rain-water tanks built of galvanized iron are found in all the houses. The water, which is in common use, contains about 17.1 parts per million of zinc, yet no harmful effects have been observed.*

In his experience the writer has been unable to trace any evil effect due to the presence of zinc in drinking-water, even when the quantity rose as high as 23 parts per million in a water which is in constant use.

It might be well to add, that in the particular case just cited the zinc was derived from a long stretch of galvanized iron pipes and the amount of the metal present was subject to great and frequent fluctuations for reasons that were not apparent.

It must be admitted, however, that, even on the assumption that the presence of zinc in a water is of no sanitary significance, its being there is nevertheless not desirable, and the probability of a pro-

* Hazen, *Eng. News*, April 4, 1907.

posed water-supply being able to dissolve the metal should be determined and reported.

———

Determination of Action of Water upon Metals.— In reporting the possible action of water upon any of the common metals such action, whether of solution or erosion should be stated in parts per million, and it is convenient to standardize the conditions governing the action by allowing one litre of water to be in contact with one square decimetre of bright metal for one hour at 15° C.

The mode of procedure followed by the writer is to submerge a piece of bright sheet metal, one decimetre square, in two litres of water contained in a wide-mouthed bottle. The water is occasionally given a gentle motion and is kept at 15° for one hour, after which time the metal in solution or suspension is determined. One hour is sufficient time to allow of the watching of metallic solvency, and let it be added, the limiting of the time of action to the standard period is important, for the rate of action of the same water is not only variable, but the ratio of the total action during different lengths of time is not a simple one. Thus, the quantity of metal attacked in ten hours is by no means ten times that acted upon during one hour.

Let it be said that although we know in a general

way that softness, acidity, dissolved gases, and the presence of much chloride or nitrate will tend towards metallic solvency, while alkalinity and hardness are rated as protective agents, yet it is far better to actually test a water with reference to its behavior towards metals than to attempt any prophecy of its action based upon analytical knowledge of what the water may contain.

————

Arsenic occurs in some waters naturally, and both arsenic and *chromium* may be present from industrial waste. Should the presence of these elements be suspected, their determination should be undertaken, in the concentrated water, by the usual gravimetric methods

ALUM

When examining the effluent from mechanical filters, it becomes essential to determine if any undecomposed coagulant (i.e., alum) passes into the filtrate. For such purpose the " logwood test " proposed by Mrs. E. H. Richards is valuable.

Boil some logwood chips in a little water for a few minutes and drain off the resulting extract. Repeat the boiling and again discard the extract. Boil for the third time about fifteen minutes and keep the extract for use.

Place about 100 c.c. of the water in a porcelain dish, add a little of the logwood extract, followed by 2 c.c. acetic acid. If even a trace of alum be present in the water the logwood will produce a violet tinge which will not be discharged upon addition of the acetic acid. A " blank " should always be run for comparison. The logwood extract is reliable for a short time only, especially if exposed to air. It is never safe to trust it when more than a day old.

Logwood for this test cannot be readily purchased, that obtainable from the druggists being absolutely worthless. The best method of obtaining it is to personally bore the chips from the centre of the log.

When examining the filtrate from a mechanical plant by the logwood test, it would be well to take the alkalinity also.

If the filtrate be alkaline, free alum cannot be present, and any logwood reaction then observed would be due to particles of $Al(OH)_3$ passing the sand bed and becoming dissolved in the reagents employed.

Lacmoid, or erythrosine, should be used as the indicator, as methyl-orange does not indicate an acidity due to alum.* (See page 19.)

It is worth remembering that a "dose" of one grain per gallon of aluminum sulphate (containing

* See Fullers' Louisville Report, 55 and 447.

17 per cent Al_2O_3) will require about 8 parts per million of " alkalinity " in the water for its complete decomposition

PHOSPHATES

Phosphates are rarely present in more than minute traces in waters fit for domestic use, although not uncommon in those which are contaminated. Excellent waters do at times contain them, however, in very notable quantities. For instance, the writer found as much as 2 parts per million (calculated as calcium phosphate) in an artesian water on the New Jersey coast.

" Hehner suggests 0.5 part of P_2O_5 per million as the limit for good waters, but many excellent waters contain more than this amount.*

To determine them Phipson's method is convenient. He takes a large measure of the water, adds a little alum solution, followed by a few drops of ammonia, and then makes the solution acid with acetic acid. The aluminum phosphate is filtered off, dissolved in nitric acid, and precipitated with ammonium molybdate solution in the usual way.†

Woodman proposes a colorimetric method which takes but a short time.‡   Take 50 c.c. of the water.

* Thresh, " Exam. of Waters," p. 80
† *Chem. News*, lvi. 251.
‡ *J. Am. Chem. Soc.*, xxiv. 737.

1. 07 sp. gr.

Add 3 c.c. HNO_3. Evaporate to dryness on the water-bath. Heat for two hours in the water-oven. Extract with cold water. Dilute to 50 c.c. in comparison tube. Add 4 c.c. ammonium molybdate (50 grammes per litre) and 2 c.c. HNO_3. Mix, and after three minutes compare with standards prepared by diluting standard phosphate solution (0.1 mg. P_2O_5 per c.c.) to 50 c.c. and adding reagents as above. A blank, using distilled water, should also be run.

MINERAL RESIDUE

Should a partial analysis of the mineral residue be demanded, which is not common except in the case of a " boiler " or a " mineral " water, one-half a litre, or more, of the water strongly acidulated with hydrochloric is evaporated nearly to dryness in platinum. When nearly dry acidify with HCl and complete the evaporation to dryness. The dry residue is heated in the air-bath at 120–130° C. until acid fumes cease, then cooled, thoroughly moistened with hydrochloric acid, digested with water, filtered and washed.

The residue is dried, ignited, weighed, ignited with sulphuric and hydrofluoric acid and determined by difference in the usual manner.

Barium, if present, will be found in the residue after volatilizing the silicon fluoride.

It should be fused, brought into solution, and precipitated by sulphuric acid.

Iron and Aluminum are weighed together as oxides after oxidation and precipitation by ammonium hydroxide followed by ignition.

Calcium is thrown out of the filtrate from the iron and aluminum by ammonium oxalate as is usual and its filtrate is evaporated to dryness in platinum and ignited to remove excess of ammonium salts before precipitating *magnesium* in the customary manner.

Lithium is determined by Gooch's method given in J. Am. Chem. Soc. XII, 214.*

Sulphates are determined by use of barium chloride in a separate evaporation after removal of silica, iron and aluminum. For " boiler waters," however, Prof. Main suggests making the filtrate from the magnesium acid with hydrochloric acid and then precipitating at once with barium chloride. This saves much time and is convenient.

C. B. Dudley, formerly chief chemist of the Pennsylvania R.R., determined scale-forming ingredients by: Determining the total solids as usual; treating the residue with 50 per cent alcohol and designating the undissolved material as " scaleforming."

* See also " Determination of Lithium," by Skinner and Collins, Bul. 153, Bureau of Chemistry, U. S. Dept. Agric.

Manganese is determined by the following rapid method due to R. S. Weston.*

Take enough of the sample to give from 0.01 to 1 mg. of manganese. Evaporate with about 25 c.c. of nitric acid (1 acid to 3 water). Gently ignite the residue or bake it for one-half hour at 130° C. Add 50 c.c. of the nitric acid and when the solution is cool add about 0.5 gramme of sodium bismuthate. Heat until the pink color disappears.

Add enough sodium thiosulphate to clear the solution if manganese dioxide is precipitated, and heat to dispel all oxides of nitrogen. This step is usually unnecessary.

To the cool solution add sodium bismuthate in excess, stir a few minutes, and filter through thoroughly washed asbestos in a Gooch filter. Wash with dilute (3 per cent) nitric acid, transfer filtrate to a large Nessler tube, and make up to 100 c.c. with dilute nitric acid.

In another tube put 100 c.c. of dilute (3 per cent) sulphuric acid and add standard potassium permanganate solution until the color of the sample is matched. From the volume of potassium permanganate used calculate the weight of manganese.

The presence of chlorides interferes with the determination. Samples which contain large amounts

* *J. Am. Chem. Soc.*, xxix. 1074.

of chlorine should be treated before evaporation with a slight excess of silver nitrate and then filtered.

DISSOLVED OXYGEN

The following method is that devised by M. Albert-Levy, of the Montsouris Observatory, Paris:

A pipette of about 200-c.c. capacity is provided with an upper and lower stopcock, the bore of the upper one being large, and the true capacity between the stopcocks is determined. Above the upper stopcock the tube is expanded into a short cylindrical funnel. The pipette is completely filled with the water to be examined, and the funnel is emptied. The cocks having been closed, the pipette is wiped off and fixed in a suitable clamp. Two c.c. of dilute potassium hydroxide solution are placed in the funnel and, by careful opening of the cocks, introduced within the pipette without the admission of air. After washing the funnel 4 c.c. of a solution of ammonium ferrous sulphate are placed therein, and, by similar means, also admitted within the pipette. In presence of the alkaline solution the oxygen dissolved in the water will in five minutes, after gentle agitation, oxidize the ferrous salt to ferric, and a mixture of the two hydroxides will shortly settle to the bottom. After again washing the funnel 2 c.c. of concentrated sulphuric acid are

placed therein, and the upper stopcock alone is
opened. The higher gravity of the acid will cause
it to slowly enter the pipette, where it will acidify
the contents and dissolve the hydroxides of iron.
The contents and washings of the pipette are turned
into a flask and titrated with the standard solution

DISSOLVED OXYGEN PIPETTE.

of potassium permanganate* already described on
page 86. A blank is now titrated containing a mix-
ture of a pipetteful of the water, 2 c.c. of the sulphuric
acid, 2 c.c. of the potassium hydroxide solution, and
4 c.c. of the ammonium ferrous sulphate solution.

* Should much chloride be present, as in sea-water, M. Albert
Levy suggests the substitution of the bichromate in place of the
permanganate of potassium.

The difference between these two titrations (acid reaction having prevented oxidation in the second instance) will give the amount of ferrous salt oxidized by the oxygen dissolved in the water. The volume of the water operated upon will be the volume of the pipette (V) less the volumes of the alkaline and iron solutions, namely:

$$V - (2+4) \text{ c.c.}$$

Report the dissolved oxygen as parts per million by weight, and report it also after noting the temperature of the water, as a percentage of the oxygen required for complete saturation at the observed temperature, making use of the following table:

VOLUME OF OXYGEN, IN CUBIC CENTIMETRES, RE-
QUIRED TO SATURATE ONE LITRE OF WATER AT
VARIOUS DEGREES CENTIGRADE. (WINKLER.)[1]

Degree.	C.C.	Degree.	C.C.	Degree.	C.C.
0	10.187	11	7.692	21	6.233
1	9.910	12	7.518	22	6.114
2	9.643	13	7.352	23	5.999
3	9.387	14	7.192	24	5.886
4	9.142	15	7.038	25	5.776
5	8.907	16	6.891	26	5.669
6	8.682	17	6.750	27	5.564
7	8.467	18	6.614	28	5.460
8	8.260	19	6.482	29	5.357
9	8.063	20	6.356	30	5.255
10	7.873				

[1] *Berichte*, 22, 1889, 1772.

Palmer points out that supersaturation of water with oxygen may be caused by the liberation of the gas through the action of either micro-organisms or larger plants containing chlorophyl.*

Deep samples for dissolved oxygen are taken by attaching to the lower end of the pipette a short rubber tube, which may be flexed upon itself by pulling a string fastened to its extremity. The pipette having been sunk with the rubber tube closed by flexion and with both cocks open, water is admitted by allowing the string to slacken. The string is again tightened and the pipette raised towards the surface. The cocks should be carefully closed before the surface is fully reached. It is still better to sink two pipettes connected together in tandem and to use the water collected by the lower one.

———

Carbon dioxide in solution tends to cause a solvent action upon metals, especially if the water be soft.

Should it be decided to include an estimation of carbon dioxide in the analysis, take 100 c.c. of the water and titrate with standard Na_2CO_3 solution, using phenolphthalein as an indicator.†

The determination of other gases present in solu-

* " Streams Examination," p. 87.
† *Chemical News*, lxx. 104.
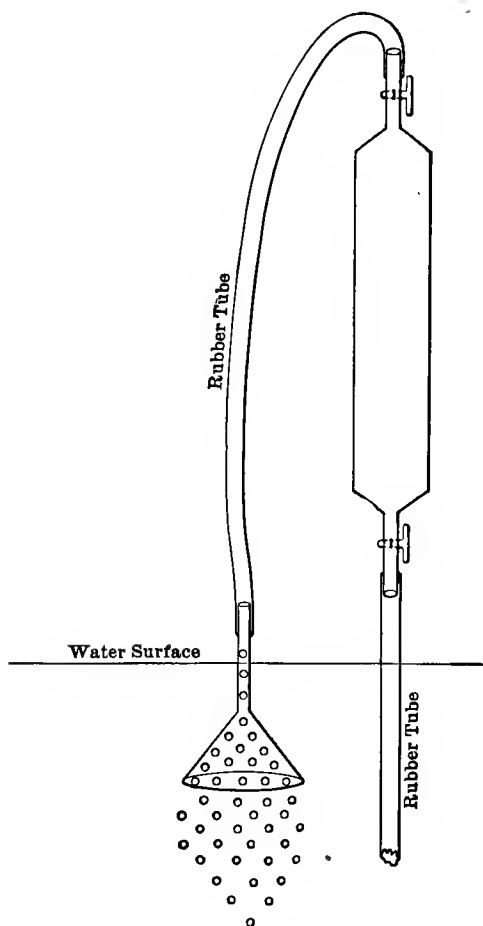
DEVICE FOR COLLECTING GASES ESCAPING FROM WATER.
(TRAVERS.)

tion is not commonly of sufficient value to repay the expenditure of time required for such work.

Of course determination of H_2S is important when dealing with mineral waters of the " sulphur " group.

An odor like that of sulphuretted hydrogen must not be taken as proof positive of the presence of that gas in a water, inasmuch as mixtures of sundry hydrocarbons will often greatly mislead the sense of smell.

Samples in which dissolved gases are to be determined should be examined in the field. They do not admit of transportation.

When it is desired to secure for analysis a sample of the gas that sometimes is observed to bubble in considerable volume from certain springs, the device illustrated on page 116 will be found of value. The whole apparatus having been filled with water and then placed in the position indicated, the gas will be sucked over into the sampling cylinder upon opening the stopcocks. The stopcocks are then closed and the sample is ready for shipment.*

PUTRESCIBILITY

Water analysts may be called upon to pronounce upon the fitness of a sewage effluent for admission

* See Travers, " Study of Gases," p. 44.

to a stream, and to say whether or not it is likely
to develop a nuisance. The writer is not prepared
to formulate here a general definition of " a nui-
sance," believing as he does that much depends upon
the character of the local conditions, but the ability
of a water to " care for itself " and oxidize its own
putrescible matter has been widely accepted as a
proper measure of its being in a condition suitable
for admission to lakes and rivers. But even this
rule must be used with judgment, for it would be
manifestly unjust to apply it as rigorously for a
large body of water as for a small.

The following procedure will give information as
to putrescibility of a water. (See "Standard Meth-
ods of Water Analysis," 1917.)

Determination of Relative Stability.—Prepare a solu-
tion of 0.5 gramme of commercial methylene-blue
in one litre distilled water. Place 0.4 c.c. of this
solution in a glass-stoppered 150-c.c. bottle. Fill
the bottle to the beginning of the neck with the
water under examination, or else fill the water into
the bottle first and then deliver the dose of meth-
ylene-blue below its surface. Insert the stopper,
being careful not to trap air below its point. The
bottle must be completely full. Place in 20° C.
incubator for ten days. Note the time required to
decolorize the colored water and record the relative

stability-number of the water. Such a number being 75 would mean that "the sample examined contained a supply of available oxygen equal to 75 per cent of the amount of oxygen which it required in order to become perfectly stable. The available oxygen is approximately equivalent to the dissolved oxygen plus the available oxygen of nitrate and nitrite."

RELATIVE STABILITY NUMBERS

Time for Decolorization (days).	Relative Stability (percentage).	Time for Decolorization (days).	Relative Stability (percentage).
$\frac{1}{2}$	11	8	84
1	21	9	87
$1\frac{1}{2}$	30	10	90
2	37	11	92
$2\frac{1}{2}$	44	12	94
3	50	13	95
4	60	14	96
5	68	16	97
6	75	18	98
7	80	20	99

For the softening of hard waters lime and sodium carbonate are used and an estimate has to be made of the quantities required.

Determination of " Lime Value."—To a known volume of the water (say 250 c.c.) in a half-litre flask add 100 c.c. of saturated clear lime water.

Boil, cool, dilute to the mark and mix. Quickly filter a part through a dry filter and titrate a measured portion of the filtrate with N/10 HCl, using methyl orange as an indicator.

Such titration will give the excess of lime present, the strength of the lime water in terms of the acid having been previously determined.

The quantity of lime required to precipitate the carbonates which cause the " temporary " hardness in the water can be then readily calculated.

Determination of " Soda Value."—Boil a measured volume of the water in a half-litre flask. Add an excess of N/10 Na_2CO_3, noting the amount used. Boil, cool, fill to the mark with distilled water and mix. Filter or allow to settle. Titrate in a measured portion the excess of Na_2CO_3 remaining with N/10 HCl and calculate the quantity of " soda " required to dispose of the $CaSO_4$ which caused the " permanent " hardness.

———

Test for " Free Chlorine " or " Hypochlorite."— In waters which have been " chlorinated." Prepare a solution of 1 gramme *o*-tolidin in one litre of 10 per cent HCl. One c.c. of this reagent added to 100 c.c. of the water under examination and allowed to stand five minutes will give a yellow color if chlorine or hypochlorite be present. The test may

be made quantitative, if required. See "Standard Methods."

———

As already stated, water results are best reported in " parts per million," but at times a demand will be made for a report in " grains per U. S. gallon," and to facilitate conversion from one form to the other the table given on the next page was prepared.

For ordinary use it is near enough to remember that " grains per gallon " multiplied by 17 equals " parts per million."

CONVERSION OF "MILLIGRAMMES PER KILOGRAMME" INTO "GRAINS PER U. S. GALLON" OF 231 CUBIC INCHES

One U. S. gallon of pure water at 60° F., weighed in air at 60° F., at atmospheric pressure of 30 inches of mercury, weighs 58334.94 grains.*

Parts per Million.	Grains per U. S. Gallon.	Parts per Million.	Grains per U. S. Gallon.	Parts per Million.	Grains per U. S. Gallon.
1	0.0583	36	2.1000	71	4.1417
2	0.1166	37	2.1583	72	4.2001
3	0.1750	38	2.2167	73	4.2584
4	0.2333	39	2.2750	74	4.3167
5	0.2916	40	2.3333	75	4.3751
6	0.3500	41	2.3917	76	4.4334
7	0.4083	42	2.4500	77	4.4917
8	0.4666	43	2.5084	78	4.5501
9	0.5250	44	2.5667	79	4.6084
10	0.5833	45	2.6250	80	4.6667
11	0.6416	46	2.6834	81	4.7251
12	0.7000	47	2.7417	82	4.7834
13	0.7583	48	2.8000	83	4.8418
14	0.8166	49	2.8584	84	4.9001
15	0.8750	50	2.9167	85	4.9584
16	0.9333	51	2.9750	86	5.0168
17	0.9916	52	3.0334	87	5.0751
18	1.0500	53	3.0917	88	5.1334
19	1.1083	54	3.1500	89	5.1918
20	1.1666	55	3.2084	90	5.2501
21	1.2250	56	3.2667	91	5.3084
22	1.2833	57	3.3250	92	5.3668
23	1.3417	58	3.3834	93	5.4251
24	1.4000	59	3.4417	94	5.4834
25	1.4583	60	3.5000	95	5.5418
26	1.5167	61	3.5584	96	5.6001
27	1.5750	62	3.6167	97	5.6584
28	1.6333	63	3.6751	98	5.7168
29	1.6917	64	3.7334	99	5.7751
30	1.7500	65	3.7917	100	5.8334
31	1.8083	66	3.8501		
32	1.8667	67	3.9084		
33	1.9250	68	3.9667		
34	1.9833	69	4.0251		
35	2.0417	70	4.0834		

*See article by the author on "The U. S. Gallon" in *Am. Druggist*, January, 1888.

CHAPTER III

BACTERIOLOGICAL EXAMINATION OF WATER

THE water expert of to-day cannot afford to take the risk of basing his opinion upon any one form of inquiry alone, and it behooves him to make himself familiar with all the means of throwing light upon the question at issue.

In consideration of the magnitude of the bacteriological field, it is manifestly out of the question, in a book of this scope, to go very far beyond a simple enumeration of the bacteria present in a cubic centimetre of the water under examination, supplemented by a determination of the probable presence or absence of germs derived from an intestinal source, thus leaving the problem of exhaustive differentiation to be discussed by writers upon bacteriology.*

These elementary applications of the science are of especial value for the testing of filters and watching any variation in their efficiency.

For such a purpose the simple count of bacteria per cubic centimetre is most valuable, and differ-

* The technique of such processes as " staining," " hanging drop," etc., will be found in any good text-book of bacteriology.

entiation is a secondary matter; the assumption being a just one that a filter which will remove the harmless bacteria may be trusted to take out the objectionable ones as well.

As to the value of the " count of bacteria per c.c." in the general cases outside of filter examination, much has been asserted to show its uselessness; and for " single-sample " examinations the objections are doubtless well taken, but for " comparative tests," such as watching the distance to which a stream of sewage is felt in a lake, or observing the relation between sedimentation and river flow, there is no question as to its being of great value.

For instance, it was through such means that Dr. Shuttleworth, of Toronto, was led to the discovery that a section of the conduit, leading from the distant intake, was broken, and that, consequently, the city supply was being taken from within the zone of pollution much nearer shore.*

For the accomplishing of the determinations that are here proposed the following culture media should be carefully prepared and kept ready at hand.†

Nutrient Broth.—Add 3 grammes of Liebig's beef extract and 5 grammes of peptone (Witte's) to one

* *Jr. N. E. Water-works Asso.*, June, 1896, 211.

† The formulæ for culture media are largely based upon the recommendations of the special committee of the American Public Health Association.

litre of distilled water. Heat on a steam bath until the peptone is dissolved. Restore water lost by evaporation.

The proper reaction of the medium should be $+1$ per cent (i.e., an acidity equal to what would be produced by the dilution of 10 c.c. of normal hydrochloric acid to one litre by the addition of the medium made neutral to phenolphthalein).

In order to secure such a reaction place 5 c.c. of the medium in a porcelain dish, add 45 c.c. distilled water and 1 c.c. of a solution of phenolphthalein (0.5 gramme phenolphthalein in 100 c.c. of 50 per cent alcohol).

Titrate (while hot) to the neutral point with $N/20$ NaOH, and from these data calculate the amount of normal HCl required to be added to the bulk of the medium in order to bring it to the desired degree of acidity, namely, $+1$ per cent.

[As ordinarily prepared, nutrient broth will usually be found to have an acidity of between $+0.5$ and $+1$, which is sufficiently near the standard reaction to make adjustment unnecessary.]

The said normal acid having been added, cool to 25° C. and filter until clear. The broth is then placed in test-tubes plugged with cotton, 10 c.c. in each tube.

Sterilization is then accomplished by heating in

an autoclave to 15 pounds pressure (120° C.) for 15 minutes.

Keep the broth and all other stock media in a cool, dark, moist place, e.g., an ice-box.

Nutrient Gelatin.—Dissolve 3 grammes of Liebig's Extract in one litre distilled water.   Add

> Gelatin (best French) . . . . .   100 grammes *
> Peptone (Witte's)   5   "

Heat slowly on a water-bath at a temperature of 65° C. until all is dissolved.   Restore water lost by evaporation.

Place 5 c.c. of the filtered medium in a porcelain dish; dilute the same with 45 c.c. water; titrate (while hot) with N/20 NaOH solution, as in the case of the preparation of nutrient broth, and from the data so obtained calculate what addition of normal HCl should be made to the main bulk in order to carry its reaction to +1 per cent.

Add the calculated amount of normal HCl and filter through cotton, using the hot-water funnel.

Place the finished medium in test-tubes, 10 c.c. in each.   Plug the tubes with cotton and sterilize in

* The gelatin should be dried for half an hour at 105° C. before weighing.

autoclave and store as described under nutrient broth.

It is best to make but a small quantity of any of the culture media at a time, as they do not keep well in stock.

Lactose Broth.—Prepared the same as the ordinary broth except that 10 grammes of pure lactose are added with the peptone and beef extract. Its reaction should be made neutral. Sterilize in autoclave as usual.

The best vessels in which to store the medium are the "Smith fermentation-tubes" in which it is to be used (see page 154).

Nutrient Agar.—When making plate cultures for organisms that develop at blood temperature it becomes necessary to employ a medium with a higher melting-point than gelatin possesses.

To make one litre of nutrient agar add 3 grammes of Liebig's beef extract, 5 grammes of peptone (Witte's) and 12 grammes of agar (dried at 105° C.) to one litre of distilled water. Heat on water-bath until solution is complete. Replace water lost by evaporation. Cool to 45° C. and then reheat to 65° C. and again replace any water loss due to evaporation. Adjust reaction to +1 as under nutrient gelatin. Filter through cotton, using hot water funnel and place in cotton-plugged test-tubes,

10 c.c. in each tube.   Sterilize in autoclave as usual.

Litmus   Solution.—Prepare a 2 per cent water solution of reagent litmus by adding the powdered litmus to the water, boiling five minutes, replacing loss due to evaporation, filtering and sterilizing in autoclave as usual.

Litmus-lactose-agar.—Prepare nutrient agar, adjust to neutral reaction and add 1 per cent of lactose. Sterilize as usual in autoclave after placing in cotton-plugged test-tubes, 10 c.c. in each tube.   One c.c. of the litmus solution, (prepared above) is added to the 10 c.c. of melted lactose agar at the time of pouring into the Petri dish (see page 157).

Sterilization of empty glassware is secured by heating for $1\frac{1}{2}$ hours at 170° C.

The best piece of apparatus to use for this purpose is the Lautenschlaeger sterilizer illustrated on page 129.

The 1-c.c. pipettes used for the measurement of the water should be plugged with cotton near the end which is placed in the mouth; the pipette should then be placed in a suitable tube containing a cotton plug in its open end, and the whole sterilized.

The writer employs cylinders of copper with close-fitting caps, wherein a number of pipettes can be placed during sterilization.

Petri dishes are conveniently sterilized in round copper boxes with tight covers, each box holding six dishes.

Water-samples for bacteriological examination are most commonly taken in 100-c.c. glass-stoppered bottles. The stopper and neck are covered with tin

Hot-air Sterilizer. (Lautenschlaeger). Sterilized Pipette.
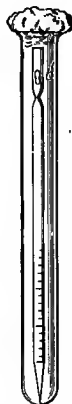
foil, secured in place by several thicknesses of cotton cloth carefully fastened, and the whole enclosed in a cylindrical copper box and sterilized in the hot-air sterilizer. Samples are also conveniently taken in bulbs of glass with long thin stems, similar to the stock articles in use for specific-gravity determinations. These bulbs can be sterilized by the direct Bunsen flame and sealed while hot. Upon

afterwards breaking off the point of the stem under water the water will enter the vessel because of the partial vacuum, and the stem can be at once resealed by using a candle-flame and a blow-pipe.

Such bulbs are convenient for taking deep samples, as the point of the stem can be broken by a separate string while the bulb is held by the sinking-apparatus.

During transportation all vessels filled with water-samples should be packed in ice, but it is very much better to make the enumeration sowings on the spot, rather than risk changes due to delay.

————

Samples for bacteriological work are more quickly damaged by keeping than are those intended for chemical analysis; thus:

SPRING-WATER, TROY, N. Y.

Kept at room temperature.

November 10........   830 bacteria per c.c.
"   12...... 8,128   "   "
"   13...... 9,433   "   "
"   15..... 12,740   "   "

Much more striking instances are given by Miquel. Thus for the Dhuis water:

	Temperature.	Bacteria per c.c.
12 noon.............	16.6° C.	57
1.30 P.M.............	19.5°	143
3 P.M...............	20.9°	456

For Vanne water:

	Temperature.	Bacteria per c.c.
Immediate...........	17° C.	56
After 24 hours........	21.2°	32,140

Also for Vanne Water:

	Temperature.	Bacteria per c.c.
Immediate...........	15.9° C.	48
After 2 hours........	20.6°	125
" 1 day..........	21.0°	38,000
" 2 days...	20.5°	125,000
" 3 days.... . ..	22.3°	590,000

Deep-well water (Frankland):   ·

	Temperature.	Bacteria per c.c.
Immediate...........	20° C.	7
After 1 day..........	20°	21
" 3 days...	20°	495,000

The last instance shows that multiplication of bacteria is not to be accounted for by the simple increase of temperature.

———

Plating for the Total Count.—Thoroughly shake the sample and transfer 1 c.c. of the water, by means

of a sterilized pipette, to a sterile Petri dish. A tube of nutrient gelatin is liquefied by immersing the tube in warm water at 35° to 40° C. Having " flamed " the open end of the tube for a moment in the Bunsen flame, the melted jelly is quickly poured into the Petri dish, and mixed with the water by tilting the dish forward and back, after which the dish is placed upon a cool level surface (preferably of stone) for the jelly to set. When the jelly has again hardened the dish should be removed to a moist, dark incubator maintained at a temperature of 20° C.

When " agar " is employed, it is melted by immersing its container in a vessel of boiling water, and then allowing the water to slowly cool to 42° C. before plating as above.

To avoid " lumpy " plating it is well to have the Petri dishes warmed to 42° C. before pouring the jelly.

Each individual bacterium, finding itself imbedded in material supplying abundance of food, proceeds to surround itself with a multitude of its offspring, until at length the " colony " so produced becomes large enough to be seen by the naked eye. These colonies, each of which corresponds to one original bacterium, are of various sizes, as shown in the illustration on page 137. Some of them do, and

STONE LEVELING PLATE FOR PETRI DISHES.

POURING GELATIN INTO A PETRI DISH.

others do not, liquefy nutrient gelatin. None of them liquefies " agar."

Petri dishes which contain sowings in " agar " should be inverted during incubation to avoid the spreading of surface condensation-water. Some workers prefer to employ porous earthenware covers for the Petri dishes. Such covers absorb the water of condensation,* but they also tend to dry the medium.

Platings in agar are incubated in both the 20°

Miquel Flask.

and 37° incubators in order to secure a comparison of the growths at the two temperatures.

For the plating of water-samples some workers employ, in place of Petri dishes, conical " Miquel " flasks, usually $2\frac{1}{2}$ inches in diameter at the bottom, with a tubulated glass cap, ground at the joint. The tubulation is plugged with cotton. Such flasks receive 10 c.c. each of the nutrient gelatin when it is first made, and are kept in stock like the

* Hill, *J. Med. Research*, 1904, N. S., 8, p. 93.

test-tubes. Taken to the field, they receive, on the spot, the measured amount of water, and the chances of contamination during transfer, and of multiplication during the journey of the water-sample to the laboratory, are thereby avoided.

It should be said that Petri dishes are also capable of being used in the field in similar manner.

————

Should the water contain over 250 bacteria per c.c. the volume operated upon should be diminished.

In place of sowing a fraction of a c.c. of water, the " dilution method " should be employed.

One c.c. or ten c.c. of the water are diluted to 100 c.c. with sterile tap water and then 1 c.c. of the mixture is plated in the usual way. Of course this dilution must be done with great care, as any error is multiplied. Should occasion demand it a higher dilution should be made.

The dilutions should be made by the use of sterile glass-stoppered bottles and sterile pipettes.

Hill found that " the actual size of the individual colonies increased in proportion as the dilutions rose: i.e., in a plate containing 3,000 colonies, the colonies were very small; in a plate containing half a dozen colonies, the colonies were relatively very large. This suggested that the discrepancy was due chiefly to overcrowding.

PETRI DISH SHOWING COLONIES OF BACTERIA. (OHLMÜLLER.)

137

If the original sample contains not over 200 bacteria, they will grow in a plate without introduction of those factors of food exhaustion or direct antagonism which we place together under the term overcrowding.

We regard as reliable only the not overcrowded plate, whichever that may be; recognizing it in the fact that the count lies between 40–200, ignoring all others, because the standard plate, containing the standard 10 c.c.'s of standard medium, will not support more than about 200 colonies without detriment to the weaker forms."*

———

Counting the colonies of bacteria is undertaken forty-eight hours after the plating, when incubation is conducted at 20° C. The agar plates incubated at 37° C. are counted at the end of twenty-four hours.

The maximum or true count would naturally be what we should desire to obtain, if it were practicable to secure it, but some colonies are of such slow growth that necessity demands that we do not wait for them.

For purposes of comparison in routine work (and usually comparison examinations are the most important form of water investigations) the above

* H. W. Hill, *Am. Pub. Health Assoc.*, 1907, 300.

periods will be found the proper intervals between the sowing and the final counting of the colonies.

Miquel does not usually count inside of two weeks, and at times waits even longer.

While such a long period is proper enough for a scientific investigation it would be impossible to allow so great an interval for the daily watching of the efficiency of a municipal filter plant.

Basing his estimate upon the examination of very many waters, Miquel gives the following figures as showing the number of colonies visible on successive days following the sowing, calling the count on the fifteenth day 1000:*

1 day	....	20
2 days	....	136
3 "	....	254
4. "	....	387
5 "	....	530
6 "	....	637
7 "	....	725
8 "	....	780
9 "	....	821
10 "	....	859
11 "	....	892

* Miquel et Cambier, *Traité de Bactériologie appliquée.*

12 days 921
13 "   951
14 "   976
15 "   1000

The counts noted on gelatin at 20° C. and on agar at 37° C., show a difference that is marked.

The higher temperature is fatal to many common water forms, while those of intestinal type are favorably influenced. It must not be assumed that the high temperature count means an accurate enumeration of objectionable organisms, for sundry perfectly harmless bacteria will grow at blood heat; nevertheless there is undoubted value to be derived from a comparison of the two counts in question.

Such irregular results as the following will be noted:

Gelatin at 20° C.	Agar at 37° C.
5268	495
240	88
37071	837
121	21
1400	82
5283	12
2033	1000

When the number of the colonies is large, counting must be done with the aid of a ruled glass plate.

The best device for this purpose with which the writer is familiar is the " Miller-McPherson " counting apparatus, which needs but little explanation beyond what is given in the illustration shown on page 143.

A good and simple modification of this has been made by Caird.

The " Wolffhügel " device which is still so commonly employed, has the disadvantage of not firmly fixing the " Petri " dish in place, so that there is no small danger of counting the same colonies more than once. Nor is it possible to make use of a " Miquel " flask as a substitute for the " Petri " dish, if the " Wolffhügel " counter be used.

The new apparatus is so arranged as to have the ruled glass plate a fixture, while the " Petri " dish rests upon a movable ebonite plate, which is raised or lowered by the wheel beneath it actuating a hollow screw. The dish may be thus always kept firm against the ruled plate, with no chance of slipping, and moreover it will be always in focus no matter what may be its thickness. The entire plate should be counted.

Both Petri dishes and Miquel flasks are counted bottom upwards.

When a Miquel flask is used the neck of the inverted flask passes through a hole in the ebonite
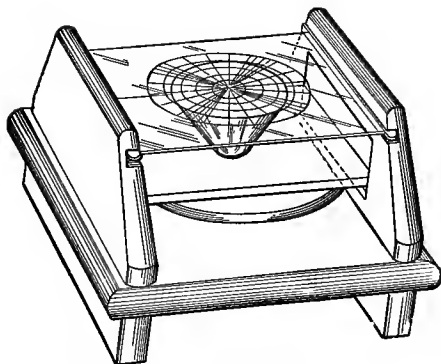
Miller-McPherson Counter.

Lens for Counting Colonies of Bacteria.
(Bausch & Lomb)

plate and into the hollow screw, while the wheel beneath raises the bottom of the flask against the ruled plate the same as when a Petri dish is employed.

The count should be made by the use of a lens magnifying $3\frac{1}{2}$ diameters. A new binocular form is now on the market. See illustration.

The " count " of bacteria per c.c. although of prime importance for filter testing is of secondary value for the rating of untreated waters. No hard-and-fast standard of comparison can be given which will prove satisfactory, although sundry have been proposed.

The following is by McWeeney:*

Pure water: *Gelatin*, 20° C. Colonies few or many; liquefiers few; chromogenic and slow-growing forms numerous.

Agar, 37° C. Sterile or nearly so.

Dirty water: *Gelatin*, 20° C. Colonies at least 500; liquefiers numerous.

Agar 37° C. Not to exceed one-tenth of the count on gelatin.

Sewage: *Gelatin*, 20° C. Colonies innumerable; liquefiers many.

Agar 37° C. Colonies innumerable; small and gray.

* *J. Roy. San. Inst.*, 31, 267.

The number of bacteria per cubic centimetre in water-samples taken from the same source at different times will greatly vary with the season and changes in local conditions. Thus the Hudson River water sampled at Troy showed the following variation in bacterial contents during the colder half of the year; similar results for a Rensselaer County spring-water are also given.

	Hudson River.	Spring.
October................	1,487	158
November........ .. { 626 / 8,128	626 / 8,128	750
December............	1,463	1,620
January..............	4,022	2,519
February.............	3,322	166
March........	....	8,520
April................ { 1,343 / 17,665	1,343 / 17,665	476

The influence of high water in the river is well shown by the difference between the early and late April samples. Surface-washing is the cause of such an increase. The effect of melting snow, and consequent surface-washing, is also shown in the March sample of spring-water.

In general it may be said that so long as a river is fed by springs, that is, during the hot months,

the bacteria tend to remain low in numbers, but with the advent of floods germ-life increases in quantity, because of the washing of the surface of the ground by heavy rainfall and melting snow. During the period when severe frost ties up all surface sources the bacteria again diminish in numbers.

Differentiation of species, as has already been said, must be largely left to writers upon general bacteriology; but a word or two may be properly spent here upon the often broached topic of the recognition of the typhoid bacillus in water, and we should also add a consideration of the tests for and the diagnostic value of the presence of *Bacillus coli communis*.

Laws and Andrewes in their report to the London County Council show that the chance of discovering *B. typhosus* in sewage is small. They entirely failed to find it in London sewage.

They examined the sewage flowing (without disinfection) from the Eastern Hospital at Homeston, which same received the dejections of forty typhoid patients.

Out of a whole series of samples examined from this latter source only two colonies of *B. typhosus* were differentiated with certainty.*

Similar experience was recorded by other observ-

* See Rafter's " Water of Lake Erie," p. 14.

ers, and consequently search for the typhoid germ in water became unusual.

Of late attention has been again directed to this determination, but even though we possessed a method of proving with certainty the presence or absence of the typhoid bacillus, such knowledge would not greatly aid us.

The information we desire is not alone the condition in which a water is to-day, but we wish to be also advised of the chances of its specific pollution to-morrow. In short, we want to guard against the use of a water which *may* become the carrier of disease organisms even though none be present at the moment of examination.

The situation is tersely summed up by Dr. W. H. Welch:

" We possess no satisfactory method for the determination of the presence of the typhoid bacillus in water. With our present methods the most which can be expected from the biological examination of water as regards this question is the determination, not of the actual presence of the typhoid bacillus, but of the possibility or probability of its presence. Our principal guide at present in drawing conclusions as to the possible presence of the typhoid bacillus in suspected drinking-water is the recognition of fæcal bacteria,

and more particularly of members of the colon group." *

We seek, therefore, some index of fæcal pollution which will indicate sewage inflow, even though such inflow be from sources which for the time being are not pathogenic.

This brings us to a query regarding the diagnostic value of the " colon group."

The *Bacillus coli communis* has its habitat in the intestines of man and the warm-blooded animals. In small numbers, it is of very wide distribution, and it is doubtful if a surface water could be found that would not furnish it, provided a sufficiently large volume of the water were examined. " Many excellent water supplies derived from upland surfaces would have to be condemned if we were to insist on the absence of *B. coli* from 10 c.c.

Even after storage in open reservoirs *B. coli* is often present in considerable numbers, owing to the numerous sea-gulls that frequent such sheets of water."† E. G. Smith‡ has found it upon standing grain. It has also been discovered in the excreta of fish,§ but that might be accounted for by its presence in the water whence the fish came. There-

* *J. Am. Pub. Health Assoc.*, xx. 502.
† *J. Roy. San. Inst.*, xxxi, 269.
‡ *Science*, xxi, 710.
§ Hill, " Public Water Supplies," p. 28.

fore it is its persistent presence in 1 c.c. samples of a water rather than its being occasionally found in those of larger bulk, that gives evidence of probable fæcal pollution.

It is certainly the author's experience that the " colon group " is widely distributed, he having found it in waters that a sanitary " survey " would unquestionably pronounce safe; but it cannot be denied that its persistent presence in small samples is an indication of pollution that must not be overlooked. Moreover, the proof of its absence serves to materially aid in formulating an opinion in favor of the purity of a water.

As stated above, water which persistently shows *B. coli* in 1-c.c. sowings is of very questionable character, and, should similar results be found when operating with sowings of 1/10 c.c., the adverse opinion is naturally still more pronounced.

The U. S. Treasury Department Standard for potable waters on common carriers requires that not more than 100 colonies shall develop on agar after 24 hours incubation at 37° C., and that not over one out of five 10-c.c. portions shall show *B. coli.**

The Mass. Board of Health† found that for the six

* Pub. Health Report, Nov. 6, 1914.
† Report of 1902, p. 247.

years 1898–1903 the raw water of the Merrimac River contained *B. coli* in 98.7 per cent of all the 1 c.c. samples examined, and that the average count of the organism per c.c. during that period was fifty-eight. Fewer were found in winter than during summer, a fact probably due to dilution by storm water.

————

Sundry bacteria are capable of inducing a fermentative action, with evolution of gas (CO_2 and H), or acid, or both, when grown in a medium containing one per cent of sugar. As for instance:

	Dextrose.		Lactose.		Dulcite.		Saccharose.	
	Acid.	Gas.	Acid.	Gas.	Acid.	Gas.	Acid.	Gas.
B. typhosus *	+	0	0	0	0	0	0	0
B. paratyphosus......	+	+	0	0	+	+	0	0
B. coli.............	+	+	+	+	+	+	0	0
B. paracoli	+	+	0	0	+	+	0	0
B. acidi lactici	+	+	+	+	0	0	0	0
B. lactis aërogenes....	+	+	+	+	0	0	+	+
B. clocæ.............	+	+	+	+	0	0	+	+

To these may be added *B. communior*, which gives gas in each of the four sugars.

The following graphic arrangement is abstracted

* *J. Soc. Chem. Ind.*, xxx, 323.

from a former report of the water committee of the
Am. Pub. Health Asso. (1912):.

<div align="center">

B. coli group.

Dextrose+
Lactose+

</div>

Dulcite+		Dulcite−	
B. communior		*B. aërogenes*	
B. communis		*B. acidi-lactici*	
Saccharose+	Saccharose−	Saccharose+	Saccharose−
B. communior	*B. communis*	*B. aërogenes*	*B. acidi-lactici*
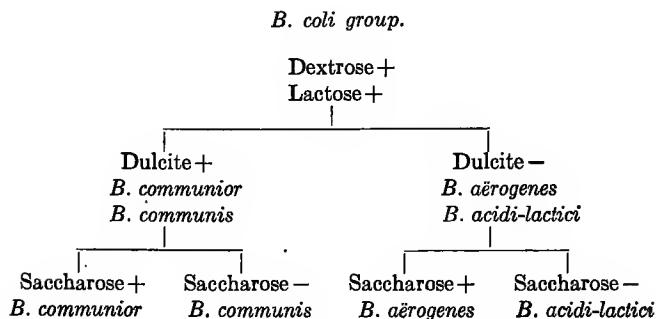
" The entire group is typical of the presence of
fæcal matter when water or sewage examinations
are to be considered."

Tests for B. coli communis.—1. To each of five
(in special cases, ten) " Smith fermentation-tubes,"
charged with sterile lactose broth, add 1 c.c. of
the water under examination. Mix by tilting the
tube, and place in the incubator at 37° C. for 48
hours.

Incubate in like manner five more fermentation-
tubes which have been sown with 1/10 c.c. of the
water, measured by the dilution method (page 136).

If any gas-forming bacteria be present, gas will
collect in the closed limb of the tube, and some
knowledge of the numbers of such organisms present
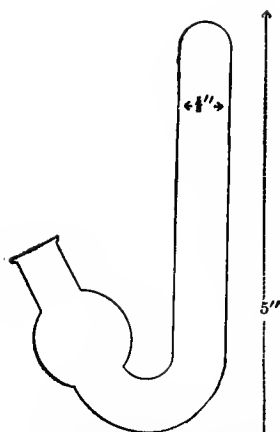
SMITH FERMENTATION-TUBE.
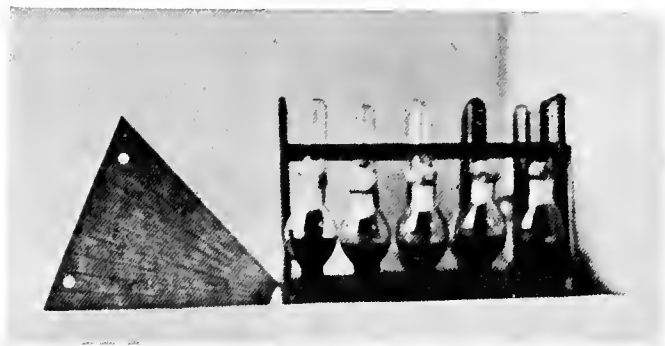
RACK HOLDING SMITH TUBES WITH FROST'S READING CARD.

may be gained by observing how many of the two sets of tubes show the reaction.*

If no gas be formed *B. coli* is absent.

2. If gas be produced its amount is stated in percentages of the length of the closed limb. *B. coli communis* will usually fill this closed limb about half full of gas.

A most convenient little device for reading the gas percentages was suggested by Frost.† A sheet of cardboard or metal ruled in converging lines is placed in the angle between the bulb and the closed limb of the Smith tube. The top of the closed limb having been made to coincide with the upper or zero line, the percentage of gas present can be read directly.

As *B. coli* usually ceases to evolve gas by the end of the first day, the total gas will often be diminished in volume on the second day, due to solution of CO_2 in the liquid present.

In the original experiments by Smith the total gas averaged 52 per cent for *B. coli*, and about 23 per cent for certain " transitional forms "; while for *B. lactis aërogenes* and *B. cloacæ* the average ran as high as 76 per cent.

Sowings, made by the writer, from pure cultures of *B. coli* gave the following averages, although the minimum readings were much lower:

Total gas.. 35 per cent
Gas formed during first day (as p. c. of total gas).... 100 "
Ratio of H to CO_2.............................. 71–29 "

3. Although *B. coli* forms its gas rapidly, evolving most (often all) of it within the first twenty-four hours, yet if the organisms should be attenuated
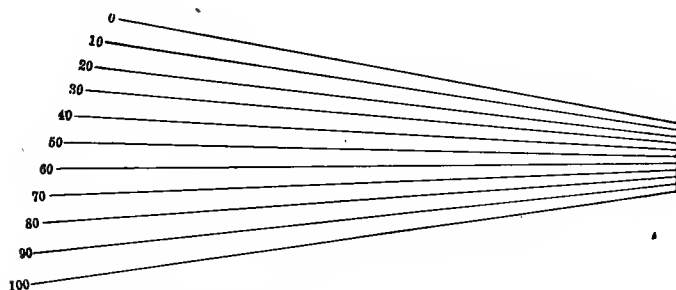
FROST'S DEVICE FOR READING GAS IN SMITH TUBES.

by reason of the pollution being not recent, then the rate of gas formation would be slower. Sundry other " gas-formers " also act slowly. Therefore, note the volume of gas formed during each day.

4. Dr. Theobald Smith holds that *B. coli* forms a gas having the approximate composition of $H : CO_2 :: 2 : 1$. The ratio found by the author is given above. With sundry other gas-producers the

carbon dioxide is the greater. To determine the CO_2, fill the bulb to overflowing with solution of KOH; close the orifice with the thumb and tilt the tube a number of times to cause the KOH to absorb the CO_2. The remaining gas is rated as hydrogen, although it contains also a little nitrogen and methane, as shown by Pennington and Küsel.[*]

5. The liquid in the bulb of the fermentation-tube should be acid to indicate *B. coli*.

6. When grown in lactose litmus agar and incubated at 37° C. for twenty-four hours, *B. coli* produces colonies of a red color.

———

The foregoing have been termed the " presumptive tests " for *B. coli*. Longley and Baton [†] have shown that they err on the side of safety. Thus out of 794 instances where the " presumptive tests " indicated the presence of *B. coli*, the use of more exhaustive methods confirmed the finding 529 times. That is the presumptive tests were accurate 67 times in a hundred.

———

For more careful search for *B. coli* proceed as follows: [‡]

[*] *J. Am. Chem. Soc.*, xxii, 560.
[†] *J. Infect. Diseases*, iv, 412.
[‡] Extracted from the 1917 report of the committee on " Standard Methods."

  I. Inoculate lactose broth fermentation tubes as directed on page 152 and incubate at 37° C. for forty-eight hours.

 II. (a) No gas formation . . . .*B. coli absent.*
     (b) Gas formation (in any amount) pass to III.

III. Make litmus-lactose-agar plate from II(b) and incubate at 37° C. for forty-eight hours.

IV. Fish two most typical red colonies from III to lactose broth fermentation tubes and incubate at 37° C. for forty-eight hours.

 V. Fish same two colonies from III to agar slants and incubate at 37° C. for forty-eight hours.

VI. (a) If IV gives no gas formation...*B. coli absent.*
    (b) If IV gives gas formation. . . . pass to VII.

VII. Examine growths on agar slants (from V) for spores.
     (a) Growths show spores . . . .*B. coli absent.*
     (b) Growths show no spores . . .*B. coli present.*

From the above it will be noted that members of " the *B. coli* group are to be considered as

(a) *non-spore-forming bacilli* which
(b) *ferment lactose with gas production* and
(c) *grow aërobically on standard solid media.*"

[Although the present routine methods of examination for *B. coli* do not call for observations of form and measurement, motility in "hanging drop,"

staining phenomena, production of indol and sundry other tests, yet the hope of new light being secured by more extensive study should lead the student to record such data and to investigate carefully all additional reactions that appear of promise.]

———

Sterilizing a water by heat is not so easy as most people imagine. Absolute sterility can be attained in about forty-five minutes by heating the water, under pressure, to 115° C.

Ordinary boiling for half an hour will destroy about 99 per cent of all bacterial life, and fortunately that which remains is entirely harmless. No pathogenic germs are capable of resisting such a temperature for half an hour.

Experimenting with Seine water, which contained, at the ordinary temperature of 22° C., 848 bacteria per cubic centimetre, Miquel found the following decrease in the numbers of organisms as the temperature was raised:

Water maintained 15 Minutes at	Bacteria per c.c. remaining.
43° C.	640
50°	132
60°	40
70°	27.2

Water maintained 15 Minutes at   Bacteria per c.c. remaining.

80°	26.4
90°	14.4
100°	5.2

For the enumeration of organisms not bacterial, in water, Prof. D. D. Jackson has devised a valuable modification of the original Sedgwick-Rafter filter.

The body of the filter is cylindrical and 2 inches in diameter. The distance from the top to the conical base is 9 inches. The small cylindrical prolongation of the cone's apex is $2\frac{1}{2}$ inches long and $\frac{1}{2}$ inch in diameter. A perforated rubber stopper, with its hole covered by a disk of fine bolting-cloth, is fitted to the smaller end of the funnel and about $\frac{3}{4}$ inch of carefully screened fine sand (between 60 and 100 mesh) is poured into the narrow tube and wet down with distilled water.

From 250 to 500 c.c. of the water under examination are now permitted to filter through the sand. After the water has run through, the sand with the material strained off by it is washed into a test tube by 5 c.c. of distilled water delivered from a pipette. The organisms, sinking in the test-tube much more slowly than the sand-grains, may be

decanted, with the water in which they float, into a second test-tube. From this decanted portion,
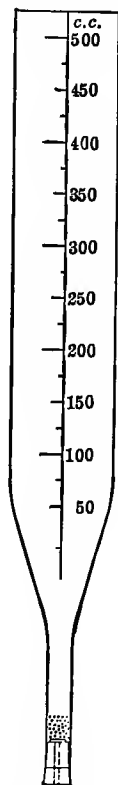
SEDGWICK-RAFTER FILTER.

after agitation, 1 c.c. is delivered by a pipette to the covered " counting-cell " which it completely fills.

This excellent device will be found of great service in recognizing and enumerating the various

COUNTING CELL FOR PLANKTON. (AFTER WHIPPLE.)
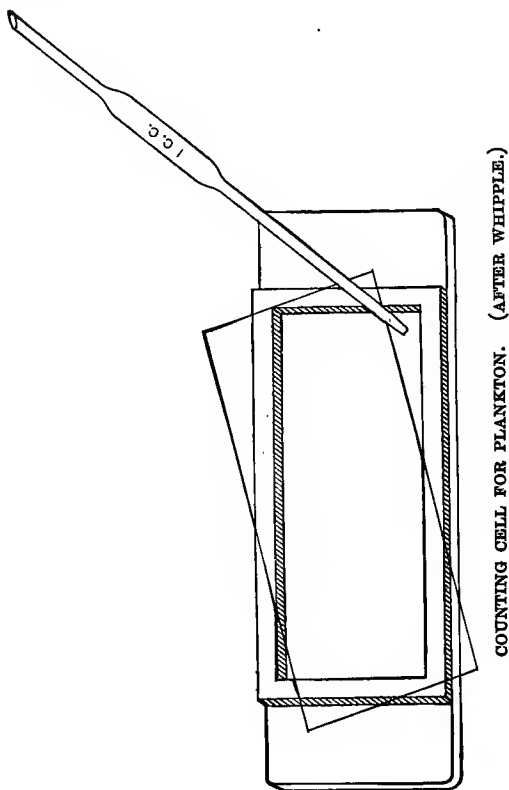
forms of life not bacterial commonly met with in waters.

For purposes of general plankton study, recourse

must be had to the writings of biologists who have made such work a specialty. Particularly valuable is a work by Prof. G. C. Whipple, " The Microscopy of Drinking-water," published by John Wiley & Sons.

APPENDIX A

INTERPRETATION OF A WATER-EXAMINATION

INTERPRETATION of a water-examination may be considered from two quite different points of view. It may mean the private weighing of evidence by the investigator himself, a procedure which finds expression in his final opinion, or it may be his attempt, often a desperate one, to make analytical data intelligible to an unscientific audience. The first is, of course, necessary and legitimate, the second is always of questionable policy, and frequently is an undeniable mistake. In former days when 'standards' were still much in vogue, it was indeed a difficult matter for the analyst to escape from 'explaining' the analytical results to the assembled council of city fathers, and deep was the irritation felt by those people that the figures given could not be explained as clearly as they might have been were the case one involving the composition

of an iron ore. Of course, those were times when the chemical data alone were considered sufficient whereon to formulate a pronouncement as to the quality of the water, and it is to be admitted that the chemist himself frequently found before him a very complex problem when he attempted to fit the results of his analysis to the sanitary facts known to relate to the water in question. Bacteriology was as yet undeveloped and its bearing upon the ' sanitary survey ' had not as yet seen the light. A sample of water taken anyhow, in any kind of vessel and by anybody, was packed off to the chemist; all knowledge as to where it came from was intentionally withheld and a complete report of its sanitary qualities was confidently expected. Is it to be wondered at that in those early days a good share of discredit was cast upon a water-examination? With the advent of bacteriology upon the scene, interest was greatly awakened. The new science promised much, and it seemed that the time had come for very positive and ready answers to the perplexing questions which had bothered us so long. Not so many years ago there met in the city of New York a sizable number of men who had gathered for the purpose of discussing the merits of a chemical *versus* a bacteriogical examination of water. Advocates of the two methods advanced arguments in support of their

special views and offered illustrations calculated to expose the weak points of their opponents. Unfortunately some remains of that spirit of rivalry still exist; but those who have the widest knowledge of the broad field of ' water-supply ' readily admit that a competent investigation suitable for determining as to the purity of a city's water service cannot be undertaken in the laboratory of either the chemist or the bacteriologist or the microscopist alone, but must be the product of a draft upon the sciences represented by all three of those men, and must, furthermore, include the findings derived from what may be termed the ' sanitary survey.' I am speaking to scientific men, who need no instruction, but perhaps over their heads a few laymen may be reached who need it sadly. And now let it be asked who are to be classed as the laymen? There is but one answer, to wit, all who have not given special study to this particular subject. The field is so wide, is increasing at so rapid a pace, and covers such a variety of topics, that even those interested in this line of work have all they can do to keep in touch with the changes taking place about them.

It is a mistake to underestimate the value of the ' sanitary survey,' by which we mean a thorough knowledge of the source whence a water comes and of the opportunities for pollution, both constant and

occasional, to which it may be exposed. In the writer's judgment it is not too much to say that if but one form of examination be possible, the 'sanitary survey' should be the one selected.

Then why not rest satisfied with such examination and permanently exclude chemistry and bacteriology from water cases; and why is not the city engineer an authority competent to express final judgment upon the matter in hand?

In reply it may be said that because of the greatly increased public interest in 'water-supply' which has developed during recent years, there has arisen a class of men who have devoted nearly their whole time to the consideration of water questions and who have brought to their aid a sufficiency of chemistry, bacteriology, and microscopy to satisfy the requirements of their calling. Such men are, because of their special training and experience, enabled to view the question from more than one side, and their conclusions have, in consequence, greater scope.

Although the writer believes that, taken alone, the 'sanitary survey' is, in the majority of cases, the most important form of examination, he begs not to be misunderstood.

No amount of inspection could be substituted for the bacterial count in testing the efficiency of a filter-plant, nor would it be of value in warding off danger

to a ground-water arising from the presence of an unsuspected cesspool.

As showing the utility of the chemical examination take the following instance for example:

A well which was most highly prized because of the cool, pleasing taste of its water was found loaded with chlorides and nitrates. Bacteriology gave no indication of pollution, and inspection of the surroundings was spurred into energy by the chemical results alone. Sewage, completely oxidized, from neighboring vaults was found to account for the abnormal items in the analytical results. At the time of the examination no harm was being done, but would the owner of the well be justified in continuing to use such a water and take his chances of the purifying action of the soil being always effective?

It is possible that some objection may be raised to the condemning of a water which shows as its only objectionable feature a chemical evidence of ' past pollution.' If the pollution be truly past and all of the nitrogenous organic matter be represented by nitric nitrogen; and, further, if bacterial examination result favorably, then wherein lies the objection to the use of a water, which, although once polluted, has regained its potable qualities? All pure waters, it may be contended, might be classed under such a head; for, after all, we are bound to use water over

again sooner or later, contrive matters how we may. All this is true enough, but there is surely a preference as to the length of time between the date of present use and the period of ' past pollution.'

It is true that every time we drink filtered river-water we are imbibing a purified sewage of greater or less concentration, and, with continued growth of our great cities, and the increased pollution of our watersheds, it would seem that the day is not far distant when a naturally ' safe and suitable ' water shall become a thing of the past, and we shall be forced to employ a purified water as our only source of supply.

Let it be remembered, however, that we can control the artificial purifying devices of which we make use, and we can repair them should they at any time refuse their work.

The case is quite different, however, when our safety lies upon the proper operation of those natural processes of purification which are beyond our power to direct. Such purification, to be satisfactory, must appeal to us as being continuously effective.

We know very well that the raising of water-vapor by solar heat will leave objectionable material behind, and we are satisfied that the result is perfect and that it will continue to be so during all time. We also know that the filtering and oxidizing power

of the soil is very great, and in general we are willing to pin our faith upon its efficiency. But we cannot avoid a feeling of uncomfortable doubt when we note that a small amount of soil has been given a large quantity of work to perform, and we naturally ask, cannot the purifying powers of such soil be overtaxed, with the result that our protective filter will become damaged at a point beyond reach of repair? Let an English case be quoted here:

" A certain farmhouse was notoriously unhealthy. The inmates had suffered at various times from diphtheria and typhoid fever. The water had been examined, and was reported to be satisfactory. Upon examining the premises it was found that there was a water-closet in the house, which was in good order, but where the contents were discharged was unknown. The drains were said to be satisfactory and never to get blocked, and upon tracing them, it was found that they discharged into a drysteyned cesspool without overflow about four yards from the well, both sunk in the gravel, which here was twenty feet or more in thickness. This well yielded an unfailing supply of water, which was used for all domestic purposes, and upon analysis it was found to be remarkably free from organic matter, It was said to be always cool, bright, and sparkling, probably due to its containing a very excessive

amount of chlorides and nitrates derived from the
sewage percolating into the subsoil, and the opinion
was expressed that the water was a concentrated
purified sewage. This was not believed at the time,
but when the cesspool was filled in and the sewage
carried elsewhere the well ran dry. There is no
doubt that in this case the same water was used over
and over again. After being defiled by the closet,
slops, etc., it ran into the cesspool, then filtered
through the soil, in its progress the organic matters
becoming completely oxidized, and ultimately it
found its way back to the well, to be utilized again
for domestic purposes. Doubtless at times, pos-
sibly after heavy rains, the cesspool contents filtered
too rapidly for complete purification to be effected,
and this impure water may have been the cause of
the ill health amongst those who consumed it."

In this instance, as in the first one given, the
danger-signal was held out by the chemical side of
the investigation alone, the other methods of inquiry
failing to detect any trace of evil.

It would seem that bacteriology deals with the
present and that chemistry, besides throwing light
upon the past, does, to some degree, prophesy what
may happen in the future.

Many a water which the bacteriologist has pro-
nounced harmless has been condemned by the

chemist because of what it might unexpectedly become at some future time; and, on the other hand, the bacteriologist has time and time again shown the presence of unlooked-for pollution when the chemist might search for it in vain.

A good instance of the saving of the situation by a 'sanitary survey' when both chemistry and bacteriology show adverse reports is to be found in the examination of water from a new well or a recently 'developed' spring. Given an old and well-situated spring upon a hillside, the desire of the owner to 'improve' the property with a view of placing the water upon the market will commonly result in a disturbance of the immediately surrounding soil. From a sanitary outlook no harm has been done the water, and one familiar with the situation will offer no objection to continuing its use, but both the chemist and the bacteriologist will secure analytical results which will require to be explained to avoid an adverse report. The writer has seen many cases of this kind.

Wells which are newly dug likewise furnish water of temporary apparent pollution. Distinction must here be made to allow for actual pollution arising from foreign substances being left at the bottom of the finished well. In such instances the evidence pointing to contamination will be found to persist.

The tying up of pollution through the action of frost is another fruitful source of error, if the judgment be controlled by the laboratory data alone. Swamp waters commonly improve in winter, and samples of them will mislead the analyst who is unfamiliar with the districts whence they come. Again, the same agency will solidify surface sources of contamination like those which produced such havoc at Plymouth and New Haven, and the laboratory examination, whether chemical or bacteriological, will, throughout a Northern winter, utter no prophecy of what is to be expected during the coming thaws of spring. Nothing short of a thorough sanitary survey can be depended upon in such instances.

The water in a tidal river may be unimpeachable during ebb flow and quite the reverse at periods of flood. How could an analytical examination at the former stage of the stream predict what might be expected at change of tide?

Instances very often arise when public clamor is heard loudly complaining of the taste and smell of water supplied to the people. Much irritation is felt whenever the senses are offended by its physical condition, although gross pollution by pathogenic organisms will be complacently accepted. This tendency of the public to be their own judge as to the

suitability and safety of the water they are asked to drink reminds one of the decision of a Mississippi court in a case with which the writer had to do about a year ago. His honor said: " It is not necessary to weigh with tenderness and care the testimony of experts. An ordinary mortal knows whether water is fit to drink and use."

Would that the ordinary mortal did know! Typhoid fever might then be relegated to the list of rare diseases, and much money and many precious lives be saved.

When odors in water occur, what is the analyst to do? By the time the laboratory is reached all smell may have left the sample, and great discredit of the scientist will follow should his statement be that the water is sound, when the users thereof know to their sorrow that something is the matter with it. An examination *in situ* is what is needed in cases of this sort, and a view of the storage reservoir backed by microscopic detection of the offending organisms will do vastly more good than any amount of chemical analysis.

A man now deals with the data of water-examination in a broad-gauged fashion, feeling that the day has gone by for blind adherence to cut-and-dried standards. He approaches his decision pretty much as does the medical practitioner frame his

diagnosis at the bedside. It may be that the symptoms of the patient do not accord with the description of the disease as found in the books, and the practitioner's attention may be called to those discrepancies by a coadjutor more recently from the schools; nevertheless the breadth of his experience assures the more mature man that his judgment is not at fault and it is experience that is of value in the end.

APPENDIX B

THE method of testing oysters for *B. coli* as employed by the Massachusetts State Board of Health is as follows:*

" The shellfish is washed with sterile water, opened with a sterile oyster knife and a portion of the shell water transferred to a fermentation-tube. The body of the shellfish is then removed from the shell, washed with sterile water, opened with a sterile scalpel and a portion of the alimentary canal transferred to another fermentation-tube. Ten individual shellfish from each sampling station are tested in this manner.

" If 50 per cent or more of shellfish from a location show *B. coli*, the location is dangerously polluted.

" After a large amount of investigation the Bureau of Chemistry of the U. S. Department of Agriculture has decided to condemn oysters sold in interstate commerce which show more than two samples out of five giving positive tests for *B. coli* types of

* *Science*, April 8, 1910.

organisms in one-tenth c.c. of the shell liquor. When oysters have been condemned on this standard, however, the examinations have been supplemented with an inspection of the beds from which the oyster were obtained, and a bacteriological examination of the water bathing the oysters from these localities.

" At the annual meeting of the American Public Health Association held in September of this year, the Committee on ' Standard Methods of Sanitary Shell-Fish Examination ' gave considerable time to a discussion of bacteriological standards, but no definite action was taken.

" The Rhode Island Shell-Fish Commission is now using the government ruling in passing upon the oyster grounds of that state, i.e., all oysters are condemned in which three out of five show the presence of colon bacilli in 0.1 of a c.c. of shell water."—*Newlands and Ham.*

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